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THE GEOLOGY

OF

BARODA STATE

BY

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PUBLISHED BY ORDER OF HIS HIGHNESS

THE GAEKWAR.

PART I.—The Divisions of the State in Gujarat Proper.

PART II.—The Divisions of the State in the Kathiawar Peninsula.

PART III.—Appendix and Glossary.

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PREFACE.

The duty of making a Geological Survey of the Baroda State was entrusted to me early in October 1891 and occupied me during the working seasons of 1892, 1893 and 1894. During those three years I visited carefully and examined closely all the minerally important regions lying within the limits of the State both in Gujarat and Kathiawar. The completion of this memoir has unfortunately been much delayed by long-continued ill-health contracted in the service of the State and by difficulties connected with the preparation of the maps and plates requisite to illustrate the memoir, the work required being of such a nature that all the most important parts had to be done by myself and did not admit of my being appreciably assisted by anyone else.

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PART I.

GEOLOGICAL FEATURES OF THE STATE IN GUJARAT PROPER.

CHAPTER I.

GEOGRAPHY AND PHYSIOGRAPHY.

THE Geography of Baroda State in Gujarat Proper is by no means simple, for the several tracts composing it, extend north north-westward from the Ambika river in Lat. North. 20° 45′ to 24° 9′ and form a band of patches of extremely irregular shape and very varied size, whose relations to each other can only be understood by reference to the map. The extreme western point of the northern end of the band lies in Long. E. 71° 50′, and the extreme eastern point of the southern end of the band lies in Long. E. 73° 59′.

These different tracts are grouped together for fiscal purposes into three districts, or "Prants," of which the southernmost is called the Nausari Prant, the central one, the Baroda Prant, and the northern one, the Kari (Kadi) Prant.[1]

The Gujarat divisions of Baroda are separated from each other by intercalated parts of British territory be-

1 The subdivisions of the *Nausari Prant* are the taluqs of Nausari
Gandevi
Palsána
Kamrej
Velachha
Mahuva (Moha)
Viara
Songad

[*Over.*

longing to the districts of Surat, Broach, Kaira, and Ahmedabad and the Political Agencies of Rewakanta, Panch Mahals, and Mahikanta.

The southern half of the Baroda territory lies about 10 miles inland from the Gulf of Cambay, except in the Nausari taluq between the Mindhola and Purna rivers, where the Baroda territory forms the seaboard; and the State possesses no seaport of any value, while owing to the silting up of the estuaries of the great rivers, no craft of any size can ascend to any point within the State boundaries.

The northern half of the State lies entirely inland along the valleys of the Mahi, Sábarmati and Sarasvati rivers.

Physiography of the State.

Physiography of the State.

The greater part of the State lies within the area of the coastal band of alluvium, which has been formed by the encroachment on the shallow Gulf of Cambay, of the detrital deposits brought down by the many rivers, large and small, which drain the province of Gujarat, the western slopes of Malwa, and the southern parts of Rajputana. The upward slope of the alluvial band, from the seaboard eastward, is very gradual, so that, except where wind-blown accumulations of loam, or sand, make small local eminences here and there,

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The subdivisions of the *Baroda Prant* consist of the taluqs of

Baroda
Sauli
Waghoria
Sankheda
Dhaboi
Sinor
Chandod
Pattad and Sison
Padra.

In the *Kari Prant* the following taluqs are met with:—

Dehgám
Atarsumba
Kálól
Kádi
Pattan
Vadavli
Sidhpur
Visnagar
Kheralu
Vadnagar
Mehsana
Vijápur.

the face of the country appears to be a dead flat. It is only as the eastern side of the alluvial flat is approached that it is interrupted by low hills, which rise up at intervals, or bounded by yet lower downs dividing the different small river courses.

The Alluvial Flat.

The width of the alluvial band is very variable, as will be seen by a glance at the map. Its greatest width is a little to the southward of Baroda City in Sankheda taluq, where the Orsang, the Unch and the Heran rivers form an alluvial bay running up eastward to beyond the eastern boundary of the State. It is in this bay that the most conspicuous inliers of the older rocks rise, like hilly islands, through the alluvial flat.

In the Southern or Nausari division of the State, the alluvial flat is very much narrower and becomes increasingly so when followed southward, as spurs of the great Deccan trap, with a frontage of nummulitic eocene rocks to the south of the Narbadda river, run westward between the principal rivers which drain the district. It must be borne in mind that the alluvial flat is very widely overlaid by important subaerial formations.

In the Kari Prant.

Orology. In the northern part of the State, the Kari Prant, the only eminences which diversify the general flat surface of the country are hillocks and ridges of blown sandy loam which rise on an average, not more than 50 or 60 feet above the general level, and only occasionally attain a height of 100 feet, or a little more. The direction of their longer axes is most frequently rather north of east, a direction approximately parallel to the winds which prevail at the present time during the dry weather when alone they can progress. This is rather an enigma as Æolian formations generally advance as it were, in battalions at right angles to the prevailing winds. This anomaly will be discussed further on in Chapter VIII. when dealing with these very recent formations in detail.

These blown loam hills are scattered widely over the plains of the Kari Prant, but a certain distribution into groups is recognizable. The principal groups noted, and which are well shown in most cases in the 1 inch maps, are the following :—

(*a*) A broad band starting from Sidhpur and running

about E. by N. parallel with the boundary of the State up to its N. E. corner. This band has a width of about 6 miles.

(*b*) A group starting from Balol 12 miles S. W. by W. of Mehsana and extending up to and a mile beyond that town.

(*c*) A thick cluster of loam hills at, and around the town of Kari.

(*d*) A long and thick cluster S. E. of Mehsana running N. E. ward for 24 miles from a little south of the Dangarwa railway station.

(*e*) A long south to north, generally rather thin cluster running nearly parallel with the valley of the Sábarmati from about 5 miles south of Vijapur to Undhai (6 miles E.N.E. of Vadnagar). In the northern part of this cluster the loam hills lie much thicker together than further south. Its length is 18 miles by about 3 miles in greatest width.

Quite in the south of the Kari Prant are three more, quite small groups, of these Æolian loam hills, namely :

(*f*) A rather thick cluster of rather small hills on the right bank of the Watrak river, a couple of miles N. W. of Atarsumba.

(*g*) A small and scattered group of rather large hills 8 miles to the S.W. by S. of group "*f*" between the Watrak and the Meswa rivers.

(*h*) A similar scattered group between the Meswa and the Khari. Several of these hills are situated near the outlying Baroda village of Baora.

In the Baroda Prant the number of eminences, deserving the name of hills, rising through, or else bounding the alluvial flat, is very small. The low downs, already referred to above, as lying between the different small rivers, lie along the eastern side of the Sauli and Waghoria taluqs. Their rise above the river valleys, which separate them, is very small in most cases, so that they rarely command extensive views over the country. Their shape, which is very irregular, is best seen on the map.

Hills in Vejpur Mahal.

Rising over the surface of one of these downs in the extreme north-eastern corner of the Sauli taluq are six small rocky hillocks—two to the N. W., two to the N., one to the N.N.E. and one E. of Vejpur; the two first rise about 60 feet and the two last about 100 feet above the general

surface, others being rather lower, but only the last forms a conspicuous landmark.

Hills in Waghoria taluq.

Proceeding southward, along the boundary, no eminence of any kind lying within the State, claims attention till the south-western corner of the Panch Mahals territory is turned, a little south of the latitude of Baroda city. Here we meet a low hill, or rise, on which lies the village of Bhairapur, south of which is a tiny scarp of basaltic trap.

In the Sankheda Taluq.

Gugalpur hill.

In Sankheda taluq, rather more than a mile N. E. by E. of the Bhairapur rise, occurs a narrow ridge of quartzites which I will designate as the Gugalpur hill; it is 2½ miles long and rises rather abruptly about 200 feet above the plain to the south and 371′ above sea-level. The boundary between Baroda and the southern parts of the Panch Mahals runs along the crest of the ridge for about 2 miles from W. to E., and then trends away from the hills, which lie E. of the last named, and no other elevations are met with till eight miles further east, where a spur of Baroda territory, which juts out some four miles northward, crosses another quartzite ridge, which I will call the Achali ridge, and includes a mile in length of it. The highest point of this ridge, which extends 7¼ miles from W. to E., is 888′ above sea-level, the highest point in Sankheda taluq, and about 600′ above the valley of the Samdhi nullah which flows past the eastern end of the ridge. This nullah separates this ridge from the eastern extension of the same quartzite series (in the Jumbugoda Thakurship) which extends eastward some five miles more to the Mahabar, or Masabar, hill, a fine bold peak rising 1,159′ above sea-level, and forming a most valuable landmark for the flat and mostly thickly wooded country to the southward.

Achali ridge.

Vidwaswami Mata hill.

Crossing the Orsang river southward, the first of the island-like inliers of the old rocks is met with in the Vidwaswami Mata hill, 2⅓ miles E. of Sankheda. This is a narrow rocky ridge rising about 200 feet above the plain at its higher southern end. At its northern end is a Trig. station which stands 338 feet above sea-level and 220 above Baroda City.

Ghora hill.

Three and a-half miles S. by W. of Vidwaswami Mata rises a rather lower hill (283′) known as Ghora hill, the eastern end and summit of which lie in Baroda territory,

while the western end, and another group of low hills, lies a mile to the S. W. in an outlying piece of the Wajiria Thakur's territory.

South of these lies a scattered group of small rocky hills which are conspicuous only because of their rising abruptly out of a dead flat.

Songir ridge. To the E. N. E., at a distance of about three miles, rises a low ridge of jungly hills close to the south bank of the Heran river, among which lie the well-known Songir sandstone quarries. The ridge is prettily scarped on the north, or river side, but slopes gently to the south.

A group of higher hills, the Punpawa dongar, lies just south of these Songir quarries, but is outside of the Gaekwari territory. It affords a very good view across the greater part of Sankheda taluq to the north, and over the Sankheda Mewas to the south, besides being a trigonometrical station which dominates the flat country and affords a very useful landmark with a fixed position.

The Songir quarry ridge is about two miles long and is very much higher at its north-eastern end which abuts on the Heran river in a precipitous scarp; the highest point is 361 feet above sea-level and about 150 above the river. To the east of this scarped bluff the ridge sinks rapidly and is lost to sight about half a mile further on. To the south-westward it also sinks down to the general level in a distance of about a mile.

Kanakua hill. The next hill to be noted, known as the Kanakua hill, rises about two miles to the north-east and is a nearly bare rock about 150 feet high above the plain, of very light coloured quartz rock with a very blocky surface and offering nothing of special interest. To the south-east of it are three small low hillocks of the same rock, which stretch away towards the Heran, but are not represented in the bed of the river near Sandia (Kundia of the map) as might be expected.

Sandia Breccia rocks. About ⅔ mile south of Sandia is a broken line of large bold rocks of quartz breccia about ⅓rd mile long; the rock which is of great beauty will be described further on (page 40.)

The Watershed rise. Half a mile south of the Sandia rocks commences a low sandstone rise, which forms the watershed between the

Heran and the Aswan rivers. The southern base of this rise corresponds pretty closely with the Baroda boundary for a distance of rather over 5 miles in an E. N. E. direction, when the boundary turns suddenly north, to run nearly 3 miles up to the bank of the Heran, while the rise itself merges into the rapidly rising country east of the boundary. Great part of the rise which averages about 1½ miles in width is covered by rather open forests which is, or should be made, a Government reserve. Much of the surface is too rocky to be arable, but the forest, if conserved, would do well and be a valuable source of timber.

Nathpur ridge.

Near the bank of the Heran at Nathpur the northern edge of the rise forms a well-defined low rocky ridge about a mile long and 2-300 yards wide. Half a mile beyond the north-eastern end of this Nathpur ridge the sandstone rise trends away from the Heran and is bounded along its northern edge by the Lonadra nullah for a distance of 2½ miles. The ground rises perceptibly as the eastern state boundary is approached and attains an elevation of 300 feet above sea-level in the extreme south-eastern corner of the Sankheda taluq, and, as above stated, the sandstone rise here merges into the general slope of the country and is completely lost sight of under a great cotton soil spread which extends far beyond the boundary into the Palasni Thakurship.

North of the Lonadra nullah and a couple of hundred yards from the bend of the Heran river rise two hillocks of quartzite which are of some geological interest and must be referred to again. (See page 38.)

Láchharas hill.

One of the chief hills to be noticed in the Sankheda taluq, Láchharas hill, lies 3¼ miles N. W. by W. of the Lonadra hills and like them consists of quartzite. It is the second highest and largest detached hill in Sankheda taluq, and the trigonometrical station on its summit stands 508 feet above sea-level. The panorama from the top is very pleasing, and geographically instructive. The view to the south-east is arrested by five fine peaks of the Satpura range; to the south are the Rajpipla hills, both ranges lying south of the Narbadda. To the south-west the hilly tract forming the western part of the Rajpipla range fades away in the distance.

View from the summit.

Phenai Mata hill.

To the east, at a distance of 10½ miles, rises in Chota Udepur the beautiful volcanic peak of Phenai Mata supposed with good reason to have been one of the active vents within the great Deccan Trap Area. Phenai Mata is surrounded by several fine hills over which it towers considerably and attains a height of 1,575 feet above sea-level. Behind it, to the east, are seen spurs of the distant Malwa hills.

Mahabar hill.

To the north are sundry hills belonging to Chota Udepur and Narukote, the finest and most conspicuous being the Mahabar or Masabar hill, the bold rocky peak referred to above, (p. 4) which rises 3 miles N. of Bodeli railway station, the eastern terminus of the Gaekwar's railway. The mural ridge, which extends westward from the peak, is also a remarkable feature.

Hills in Amroli Mahal.

In the outlying Mahal of Amroli are a few small hills of trap, one half a mile south of Nawagam on the south boundary of the state formed by the rocky outcrop of a large trap dyke. The extreme south end of the Mahal is occupied by a group of Trap hills 2 to 300 feet high, part of the spur of the Rajpipla hills north of the Tapti.

Loam hills near Makni.

This completes the enumeration of the eminences along the eastern side of the Baroda Prant, excepting only a few hillocks of blown loam in the Makni subdivision of Sankheda taluq, between the Orsang and Unch rivers, which rise from 25 to 50 feet above the surrounding country, many of them being all but hidden by trees growing on and around them. The loam hills have a linear arrangement, their axes having a strike of about 15° north of east, which is the prevalent course of the wind, a true sea-breeze, which blows during the early months of the year. A solitary example of such a loam dune to the south of the Unch river occurs half a mile N. W. of Kosindara.

Eastern hills in Velachha taluq.

The next set of eminences claiming to be noticed, forms the hilly tract in the eastern half of the Velachha taluq lying between the Narbadda and Tapti rivers. The hills are detached masses of Deccan Trap rocks rising from an undulating country, and both are to a considerable extent jungle clad. Many of the hills are really ridges formed by the upstanding of dykes of harder trap running through

the softer mass of the flows, which have been more extensively weathered away. The hills form a thick cluster in the south-eastern corner of the taluq and there attain their greatest heights from 400 to 639 feet above sea-level. They must be considered as spurs and outliers of the Rajpipla hill range, and show many dykes whose courses agree with dyke systems occurring in the main range.

Ghalha ridge in Kamrej taluq.

Stretching down south from near the southern boundary of the Velachha taluq, and crossing a bit of the Surat Collectorate into Kamrej taluq is a low narrow ridge of lateritic hills which are the most westerly eminences in that region deserving of notice, but more on account of their geological interest than of their topographical importance. The southern point of this ridge, which is close to the Tapti east of Ghalha, is the only rise in the Kamrej taluq, with two exceptions, to which the name hill can be given; the exception is a small island formed by the Tapti just below the town of Kamrej by cutting a deep channel behind a high cliffy mass of loam in the left bank of the river.

The other exception, is a small hill of laterite rising about 100 feet over the alluval flat south of the Tapti and lying 2½ miles S. E. by E. of Sioni and 10 miles from Kamrej.

Nanchal hills in Songad taluq north of the Tapti.

Recrossing the Tapti river and passing east through Mandvi (Surat Collectorate) into the northern half of the Songad taluq, we find the hills forming a most complicated plexus, caused by the deep erosion of a slightly domoid plateau, the summit of which lies much nearer to the Tapti than to the Narbadda. I will call this group the Nanchal hills, after the principal village standing on them. The summit of the plateau, Toran hill, has an elevation of 1,334 feet above sea-level. It lies some three miles south of the true watershed, the highest elevation of which is but little over 1,000 feet. The erosive action has been far more intense south of the watershed than to the north of it, which was in some measure, no doubt, due to the more violent impact of the S.W. monsoon rains. Whether any difference in the durability of the rocks may have contributed to this result could not be decided without a closer survey of the country than was practicable in the time at my command. Few of

the hills form distinctly circumscarped plateaus, the trap flows being much less distinctly bedded than those of the southern part of the Deccan Trap area, or those seen in the Pavagad mass 27 miles N. E. of Baroda.

Hills in Songad taluq east of the Tapti.

To the south-east of the Vajpur reach of the Tapti and to the north of the Nesu river, an important affluent from the east, is a very hilly tract, but the hills do not form a labyrinthine plexus as they do to the west of Vajpur, and their highest points are all under 800 feet high. Geographically considered, the hills north of the Tapti are to be regarded as the southern spurs of the Rajpipla ranges. South of the Tapti the Songad taluq is but slightly hilly to the north of the great east and west high road which leads from Nandurbar to Surat. Songad fort hill is the only important one and it stands up very boldly 678 feet above the rolling plain around it, and 1,078 feet above sea-level. In form it is rudely conical. The views from the top are very fine and interesting to the north-east and south, and in really clear weather must be very beautiful, including as they do the bold peaks of the Rajpipla and Satpura hills on the north, the great plain of Kandesh to the east, and the noble masses of Saler (5263′) and Maller (4760′) and other fine peaks at the northern extremity of the great Sahyadri range to the south-east. Songad hill and the plexus to the N. W. of it must be regarded as outliers of the Sahyadri range and the hills between it and the main range to the S. E. and S. as spurs of the latter.

Songad hill.

Rupgad and other spurs of the Sahyadri Range.

The most northerly of the great spurs running out from the north-western corner of the Sahyadri range bifurcates into two minor, but yet considerable spurs, the northern of which stretches north-westward to within six miles of Songad, and a number of detached hills lying between, clearly show its former greater extension in that direction. The southern spur separates the northern one from the valley of the Jankhri river. South of the latter spur and lying partly in the wild hilly tract known as the "Dangs" is another great spur, which includes at about 7 miles from its western extremity, a well-known fortified hill, the "Rupgad" or silver hill, a place of some importance in former times. The highest point in these several spurs, so far as they run in the Songad taluq, are as follows: On the

northern spur going from west to east 1235′, 1350′, 1381′, 1771′ in a distance of 7½ miles. On the southern spur 1003′, 1309′, 1505′, 1866′, 1728′, 1619′, 1592′, 1728′, 1631′, 1686′ in a distance of 15 miles. On the Rupgad spur 836′, 937′, 1174′, 1399′, 1682′ (Rupgad) 1814′, 1884′, 1898′, 1815′ in a distance of 22 miles westward in a straight line. South of the Rupgad spur flows the Purna river which rises on the western slopes of the true Sahyadri scarp below the Malaghatia peak (4358′) 1½ mile W. of which is a tiny outlier of Baroda territory in which stands a hamlet of the name of Khokavilier. A few miles south of Malaghatia hill rises the fortified peak of Salér which belongs to Baroda. The peak attains a height of 5263′ and is the third highest point in the northern section of the Sahyadri range, the two highest being Patta fort (5587′) and Kalsubai (5427′) lying south of Nàsik. I was unfortunately unable to reach this Ultima Thule for want of time.

Hills in Vyara taluq.

The orography of the northern and central parts of Vyara taluq is well shown in sheet 34 of the topographical one-inch series. None of the hills near Vyara are of any great size. The largest is the 596 foot trigonometrical station hill 5 miles N. E. by N. of the town, which may be called Agaswan hill from the nearest village to it on the east. To the north of it is a thick cluster of lower hills which continues northward to within a mile of the Tapti, to the drainage area of which they belong. They are the western extension of the cluster above referred to as lying to the north-westward of Songad.

Prevalence of N.—S. ridges.

The hills which rise along the eastern boundary of the Vyara taluq are the extremities of the spurs jutting out west from the Sahyadri range, and differ from the hills further north, in having a north and south strike for their axial ridges instead of a more or less east and west strike as in the trans-Tapti hills.

The various scattered low ridges in the north-western part of the taluq are all dyke outcrops or crests. In the south-western part such dyke crest-ridges are very much less common.

Hills in Moha taluq.

The hills, which occur in the eastern part of the Moha taluq, lying between the valleys of the Purna and the Káveri rivers (the latter the most important southern tributary of the Ambika river) are like those in the southern

half of the Vyara taluq, the western extremities of the spurs of the Sahyadri range which have crossed the Dangs territory. Like the hills in Vyara taluq, mentioned above, they are characterized by having their axes in a more or less south to north direction instead of the east to west direction so prevalent in the hilly country north and south of the Tapti. The culminating point in Moha taluq is 1240′ above sea level, and several other peaks exceed 1000 feet in elevation. Outlying hills worthy of separate mention do not occur in the Moha taluq.

Hills in Gandevi taluq.

The hills in Gandevi taluq are but six in number and all of very small size, and would be passed by without notice but that they rise out of the low alluvial flat. Three out of the six lie on the east side of the taluq a little more than two miles E. of Gandevi town. The two southernmost are parts of a ridge running north-eastward for about a mile; the highest rises about 150 feet above sea level. They consist of trap rocks. Of the other three, which are all composed of laterite rock, one forms a low ridge about half a mile long lying between Gandevi town and the trap hills just mentioned. The other two lie both of them to the north of the town at the distances of $1\frac{1}{4}$ and $1\frac{1}{2}$ miles respectively. The top of the larger and more northerly hill is 88 feet above sea level.

Hydrology. The drainage of the Gujarat divisions of Baroda State all falls westward into the Arabian Sea, and excepting that of the most northerly taluqs which are drained by the Banass and Saraswati rivers into the Runn of Kach, falls into the Gulf of Cambay which receives such a vast amount of silt brought down the larger rivers that it is rapidly being silted up, as shown by the present condition of the harbours of Surat, Broach and Cambay. Not two centuries ago these seaports were visited by fleets of shipping of the ordinary size of the traders of those days. Now they are with difficulty reached by vessels of as low a tonnage as about 30 tons.

The principal rivers.

The four principal rivers falling into the Gulf of Cambay are the Sábarmati, the Mahi, the Narbadda and the Tapti. Of much smaller size are the Dadhar between the Mahi and the Narbadda, the Kim between the Narbadda

and the Tapti, and to the south of the latter the Mindhola, the Purna and the Ambika.

The Sábarmati only skirts the eastern side of the Kari Prant for a distance of 36 miles from Virpur in Kheralu taluq, where it first touches the Baroda territory. The river then enters the State and flows through it for 18½ miles when it enters Ahmedabad collectorate and receives no affluent of any size while in the Baroda territory, but further down it is joined by the Kari, the Meswa and Vatrak, which drain the outlying patches of Baroda territory forming with the detached mahal of Atarsumba the Dehgam taluq. The Sábarmati.

The Mahi similarly only skirts the northern side of the northern extremity of Sauli taluq, and receives some seven miles N.N.E. of Sauli the waters of the Mesri and 1½ miles lower down the united Goma and Karad which flow for a few miles through part of Sauli taluq. The central part of Sauli taluq discharges its superfluous rainwater through the Meni which falls into the Mahi 8 miles west of Baroda. The Mahi.

The Dadhar is formed by the union of the Dev and the much smaller Dadhar to the northward of Dabhoi. Some 20 miles down stream and 15 miles S. W. of Baroda it receives the Vishwamitri which rises on the western slope of Pavagad and flows in a very serpentine course (but with very small oscillations) past Baroda, 3½ miles above which it is joined by the Surwa, a tributary from the east which has been dammed back in its upper course to form the great reservoir at Ajwa. The Dadhar.

The Narbadda itself only skirts the south sides of the outlying patches of Tilakváda and Karnali and then the south side of the Baroda Prant at Chandod and Sinor, but its northern tributary the Orsang, or Or, after being joined by the Unch and Heran, which have drained the eastern part of the Sankheda taluq, brings it an important accession of water. The outlying Mahal of Amroli is drained by the little Men and Aswan rivers which fall into the Narbadda at, and 2½ miles below, Tilakwada respectively. The Narbadda.

South of the Narbadda the Kim, which rises in the Rajpipla State, flows south-westward through the Velachha taluq, for a distance of nearly 30 miles. The Kim.

The Tapti, or Tapi of the Gujarati people, flows for a distance of 43 miles through and past Baroda territory in The Tapti.

Songad and Vyara taluqs. Further down it flows for 23 miles through Kamrej taluq and to the north of Surat, skirts the outlying Baroda township of Variao for 2½ miles.

The Mindhola. The Mindhola rises in Songad taluq, flows westward through the Vyara and Bardoli (Surat) taluqs, skirts the southern side of Palsana and the northern side of Nausari taluqs, and finally opens into the Gulf of Cambay through a broad tidal estuary close to the mouth of the Tapti.

The Purna. The Purna river rises on the western slope of the Sahyadri range and flows through the rugged hill tract, tributary to Baroda, known as the Dangs. It then flows through the central part of Vyara taluq, where it receives the waters of the Jankhri and through the Moha taluq and skirts the town of Nausari on its northern side.

The Ambika. The Ambika river rises also in the Dangs, but in their south-western part; it flows through the southern halves of Vyara and Moha taluqs, and skirts the northern and western sides of the Gandevi taluq and opens into the Gulf of Cambay 8 miles W. by N. of Billimora.

Only the Narbadda and Tapti rivers are navigable above tidal influence, and then only for very light craft, but their navigability might be much further extended, by the use of stern wheel steam launches, which can be built to run in much shallower water than can be made use of by sailing craft, of much smaller tonnage.

Climate. The climate of Baroda proper, that is the Gujarat district, is very different at the opposite ends of the State, the southern taluqs having a climate that is decidedly moist though less so than that of the typical West Coast, or Konkan, while the northern taluqs have a dry climate nearly approaching to that of Southern Rajputana. The

Rainfall. rainfall in the south averages about 58 inches. Around Baroda it has diminished to 37·33 inches which was the average for 10 years up to 1881, and in the northern division, the Kari Prant, the average is as low as 32.

Temperature. Extremely few temperature observations made in the State are recorded in the *Gazetteer*, and a return lately obtained from Baroda is so palpably wrong that no reliance whatever can be placed upon its data.

An approximately correct idea of the temperature variations in Gujarat may however be arrived at by supplementing the data contained in the *Gazetteer* with others

obtained at the meteorological stations at Deesa and Surat, the former being only a few miles north of the northern boundary of Baroda State and the latter lying near the southern extremity of the State by the territory of which it is surrounded except to the west. These data are taken from "The Climates and Weather of India," a very able and reliable book by the late H. F. Blanford, F.R.S., formerly Meteorological Reporter to the Government of India.

From the tables there given (pp. 306 and 322) the following data are extracted :—

	Min.	Max.	Highest recorded.	Lowest recorded.	Mean annual range.	
DEESA...	40°	112°	118·6°	34	72°	Observations extending over 11 years.
SURAT...	48°	109°	113·2°	45·3°	61°	Observations extending over 9 years for highest and over 8 years for lowest temperature.

From the above it will be seen that the climate of the Baroda State, and adjoining parts of Gujarat, is an extreme one, especially in the northern parts, when compared with that of the southern parts of the Peninsula.

Transparency of atmosphere.

One point of difference between Gujarat and Western India generally, and the south of the Peninsula, which struck me forcibly, is the much lesser degree of clearness of the atmosphere, prevailing in the former than in the latter. This want of atmospheric transparency is observable as far south as the latitude of Belgaum and Goa. In the south in the case of mountains quite as near the sea, *e.g.*, in South Travancore near Cape Comorin, the distant view was as clear all day long as near Goa, and in Gujarat, in the early morning only. The cause of this phenomenon I am not prepared to explain, but it is very real and will be perceived at once by any one wishing to make sketches of the landscapes, from nature. Near Cape Comorin and as far north as the Nilgiris and Shevaroys sketching was practicable at any time in the day, but 7 degrees further north in the Western Ghats above Goa mists began to gather already before noon, and veiled more than half the beauty of the landscapes for the rest of the day. In Gujarat this is also the general rule, while near the falls of Gersappa in latitude 14°14′ N. the atmospheric conditions were of an intermediate condition.

Is there any connection between these optical pheno-

mena and the occurrence of the malaria seasons? To the south of a diagonal line drawn roughly across the Peninsula from Merkara to near Bezwada, the cold season is healthy on the hill ranges, but the malaria season begins about the middle of February and reaches its greatest intensity in jungly regions in April and May before the burst of the S.W. monsoon. North of Lat. 13°N. *per contra* the jungles are at their healthiest in April and May and highly malarious in the cold season. Whereabouts exactly the change takes place I have not been able as yet to ascertain by my personal experiences of travel, nor have I met with any one who could offer me any rational explanation of this curious difference of the climates. The malarious jungle tracts of Gujarat are held to be deadly to the non-acclimatized, from the end of the S. W. monsoon to the beginning of April, and my own brief experience assured me that this popular belief was well founded and that explorations of the country must be undertaken in conformity with the local experiences of the seasonal prevalence, or absence, of the malarial influences.

In tracts but recently cleared of jungle, such as great parts of Sankheda taluq, the malarious influences are modified, for in the cold weather though there was much malarial fever in my camp, it was of a mild type and yielded easily to treatment. I myself escaped with mild attacks of neuralgia!

During the rains the climate of Baroda is very damp (as a rule) and in consequence of the comparative nearness of the Indian desert very hot, and therefore steamy. Rain falls at frequent but irregular intervals and the S. W. monsoon ends as a rule in September. A few showers occasionally fall about Christmas, and in January 1892 a few trifling thunder showers fell to the eastward of Sankheda. In 1893, which is said to have been a very exceptional year, smart rain fell on several days in February in the Kari division. In the Vyara, Moha and Nausari taluqs showers fell on several days in May and the beginning of June before the true burst of the S. W. monsoon which began on the 11th June.

In November 1893 a heavy cyclone in the Arabian Sea off the Coast of Cutch extended inland to far beyond Ahmedabad, and rain fell over nearly the whole of Gujarat.

CHAPTER II.

SUCCESSION OF ROCKS.

The rocks met with in the Gujarat divisions of Baroda State are referable to the following systems and groups, which are here arranged in descending order:—

VI. Recent (*b*) Subaerial formations. Blown sands; soils; the great blown loam or "Loess" formation; fluviatile and marine alluvia. Recent and Post Tertiary.

(*a*) **Old alluvia of the great rivers.**—Consolidated grits and ferruginous gravels of the Sabarmati, Mahi and Tapti. Quarternary deposits.

V. The Eocene (Nummulitic) System. Clays, cement stones, limestones, conglomerates and laterites, of the Kim and Tapti valleys. Laterites and sandstones of the Sábarmati valley. Laterites of the Purna and Ambika valleys. Tertiary.

IV. The Deccan Trap (Cretaceous) and Intertrappean rocks. Traps and intertrappean rocks of the Mohar valley (Atarsumba). Traps and intertrappean rocks of the Mahi valley (Sauli taluq). Intertrappean rocks in the Vishwamitri. Traps in the Dev river. Traps in the valley of the Heran. Spurs of the Rajpipla hills north of the Tapti. Spurs of the Sahyadri range south of the Tapti. Dykes traversing the southern trap area. Cretaceous.

III. The Bagh Series. Songir conglomerates and sandstones in Sankheda taluq, and conglomerates and limestones in Sáuli taluq. Marine. Cretaceous.

II. The Champanir System. Quartzites forming the hills north of the Orsang river. Quartzites, limestones, calcareous schists, clay schists and slates in the valleys of the Heran and Aswan rivers. Sub-metamorphic.

I. The Archæan rocks. Granite with pegmatite veins of the Upper Sabarmati valley. Granites, gneisses and crystalline limestones of the Orsang and Unch valleys, Sankheda taluq. Intrusive rocks: Pegmatites, Quartz reefs, and Trapdykes. Crystalline.

Of these several groups, the subærial formations consisting mainly of the great loess or blown loam deposit, cover by far the greater part of the country. They are underlaid by the old alluvia of the great rivers which are nearly co-extensive with them in the area they occupy, but as a rule they are exposed only in the deep cut river valleys. To the south of the latitude of Baroda city, the loess itself is largely obscured by extensive sheets of black soil, which however I only regard as an ordinary soil and have not shown in the maps.

The Deccan Trap rocks stand second in respect of the area they occupy, and are followed; but at a long distance by the Eocene (Nummulitic) rocks. The Archæan granites, and gneisses and the lower cretaceous rocks occupy about equal areas, of small extent, while the Champanirs are exposed only over an area of about 3 square miles and this in about 20 different small patches.

PREVIOUS OBSERVERS.

Very little attention had been bestowed on the rocks lying within the state prior to the author's appointment to make a survey of its geological features.

Dr. Lush, 1836.

1. The earliest writer known to have written about rocks actually within the limits of the state was Dr. Charles Lush, who in a paper of "Geological Notes on the Northern Concan, and a small portion of Guzerat," published in the Bengal Asiatic Society's Journal (Vol. I., p. 763, 1836) refers, as follows, to the neighbourhood of Gandevi: "At Gundavie are strata of clay containing kunker, and from this point we take leave of trap as well as of shell sandstone. Kunker and clay of various forms now present themselves in the only sections seen between this place and Surat."

Lieut. Fulljames, 1838.

2. A few remarks on the geology of Baroda State occur in Lieut. (afterwards Major) Fulljames's paper, 1838. He refers, *inter alia*, to the lowness of the south side of the city of Baroda.

He mentions that about a mile S. W. of Wasna (on the Heran) a few rocks appear which are of limestone formation apparently a greyish marble. These escaped my notice, though I examined that particular corner very closely, but it is very probable that they are hidden under the

great shingle bank which the river has lately been accumulating west of Sihadra. This limestone is doubtless a member of the Bagh or lower cretaceous series to which belongs the close grained whitish sandstone which followed in a mile and which at Chametha, just outside the Gaekwari boundary, dips W. and S. W. and is rippled.

Lieut. Fulljames wrote a description of the Agate mines at Rattanpur near Broach which he visited in 1832. An earlier and fuller description of them had been given by Mr. John Copeland (or Copland?) of the Bombay Medical Service to the Literary Society of Bombay. (Read 28th March 1815, and published in their Transactions M. I., p. 289, 1819.) These papers are of special interest for Baroda, as important beds of similar agates are met with among the nummulitic rocks in Velachha and Kamrej taluqs (see pp. 73 and 75).

Mr. John Vanpell, 1839.

3. The next writer who wrote about geological facts concerning actual Baroda territory was Mr. John Vanpell, who published a brief paper with the title "Desultory Notes and Observation on various places in Guzerat" in the Proceedings of the Bombay Geographical Society (February 1839, Vol. II., pp. 51—52). In the section called "Journey to the Mahajam River," after describing the interesting ruins of the old fort built by Sultan Mahomed Begrah, King of Guzerat, on the left bank of the river he proceeds to notice the occurrence in the river gravels, a little distance above the junction of the Mahajam with the Watrak, of agates of great beauty and value. To quote his own words, he says: "This is the river and spot resorted to by the natives after the first and second fall of rain to gather the valuable agate so much prized by the nations of the West." The stones are found in the bed of the river varying in size from that of a mango to a melon. Externally they have nothing remarkable to distinguish them from the other stones in the river, but on breaking a piece off the edge they are easily recognized. The natives term them "Akeek" and "Khareesh." The most beautiful and valuable are Mocha stones and moss or bush marked agates. The Borahs are the only people who set any value on them, the native inhabitants of the vicinity making no distinction in this respect b -

tween these agates and the common pebbles of the river." Reference to these very interesting stones will be found in Chapters VIII. (p. 73) and IX. (p.).

Mr. A. B. Wynne, 1868.

Some remarks on geological features occurring within Baroda territory were made by Mr. A. B. Wynne, F. G. S., of the Geological Survey of India in his geological notes on the Surat Collectorate, Season 1862-63, published in 1868 in Vol. I of the Records of the Geological Survey of India, but he does not particularize the fact of such observations referring to Baroda territory, so, as the same observations were mostly reproduced in Mr. W. T. Blanford's great paper on Western India[1] the work next in turn that has to be noticed they may be left for consideration till further on.

Mr. Wm. T. Blanford, 1869.

This important and most interesting work, published in 1869, threw more light on the geology of the central parts of Baroda state and the country surrounding it than anything that had preceded it and deserves special mention. It is accompanied by the first geological map of this region published, and on this are shown several important features as to the distribution of the gneissic rocks, the Champanir beds, the Bagh beds and the Deccan Trap in the Waghoria and Sankheda taluqs. Dr. Blanford and his colleagues had not the advantage of possessing the capital one inch topographical maps of this part now existing, and which indeed were not available for many years after the time of their visit. The very rapid traverses they made across the country, prevented them from detecting many minute features which I have now shown in the maps accompanying this memoir. The position of the nummulitic beds in the Velachha and Kamrej taluqs are given with tolerable accuracy in the little coloured map Plate I. and the description of these rocks exposed near Galha in the banks of the Tapti is very good. The discussion of the general relations of the different rock systems met with, is very clear and cogent and shows a masterly insight into the general structure of the country.

Dr. T. Oldham.

In his paper on the Thermal Springs of India, part 2 of

1 On the Geology of the *Tapti* and *Lower Nerbudda* valleys and some adjoining districts, by William T. Blanford, Assoc. Royal School of Mines, F. G. S. C.M.Z.S., Dy. Supdt., Geol. of India, Mem. Geol. Survey of India, Vol. VI., p. 163.

Vol. XIX. of the Memoirs Geol. Survey of India (1882), page 11, the late Dr. T. Oldham gave a brief reference to the famous hot spring of Unai in Vyara Taluq and discussed the proper name of the spring which he called the Anavál spring.

Mr. F. Elliot, Baroda State Gazetteer.

The remarks on the geology and topography of Baroda contained in the volume of the *Bombay Gazetteer* treating of the state which was compiled by Mr. F. A. H. Elliot, Bo. C.S., and published in 1883, are perfectly insufficient to give a clear idea of the structure of the country.

Maps of Baroda State.

No general map of the Baroda state of any merit was available for the construction of a geological map and such general map still remains a great desideratum. The general map of Bombay Presidency on the scale of 8 miles to the inch is a good map as far as it goes, but the scale is too small to be really useful. The topographical sheets on the scale of an inch to the mile are really excellent maps. In all the many thousands of references I made to them in three years field work, I only came across two solitary mistakes, and those of very minor importance. Unfortunately all were not published when I commenced work, and two that I needed very greatly (sheets 183 and 185) were not in existence in 1892 and 1893, tho' I got them in 1894. Unluckily too the sheets of the Indian Atlas including the eastern side of the country were not procurable for love or money, nor, as far as I am aware, have they yet been published. The different volumes of the *Bombay Gazetteer* descriptive of the several collectorates Surat, Khandesh, Broach, Kaira and Ahmedabad and agencies Rewa Kanta, Panch Mahals, Mahi Kanta and Kathiawar and the adjoining states of Cambay and Palanpur surrounding and intermingled with the many outlying pieces of Baroda state are furnished with very poor little scrubby maps utterly unworthy of the often ably written Gazetteers they accompany. Little maps like these, without lines of latitude and longitude, and showing no names of even highly important places in the adjoining territories, seem to have been specially designed to hinder strangers and new-comers from readily acquiring a knowledge of the geography of the countries they profess to deal with.

CHAPTER III.

THE ARCHÆAN ROCKS.

The principal areas.

These are granites and gneisses, with associated crystalline limestones, occupying two areas of moderate extent in the Sankheda taluq and a few small, and, with the exception of two, unimportant inliers which show here and there through the great alluvial spread. A third archæan area, of small extent, which occurs far north in the bed of the Sabarmati river at Virpur in Vijapur taluq, will be described first.

(*a*) **The Virpur Granite Area.**—This very small area occurs in the bed and banks of the Sábarmati, where the river course is cut by Lat. 23·45 North, and is the southernmost point of an outlier of the granitic region lying east and south-east of Palanpur. The part of this outlier included, in the Virpur area is 2¼ miles long, from N. to S. in its extreme length, measured from the Gaekwari boundary to the most southerly outcrop.

The rock is of a pale pinkish to greyish pink colour, due to the orthoclase felspar which predominates largely over the bluish diaphanous quartz and black mica. The granite is a very hard and tough rock of great density, and comparatively but little cut up by jointing, and capable therefore of being quarried in large masses, susceptible of very high polish. The principal master joint is a nearly horizontal one, which causes the rock to weather into very large tabular masses, which are really extremely oblate spheroids. One fine example of these measured about 40 feet by 30 from 2-5 feet only in thickness. In the northern part of the area the texture of the granite may be described as "moderately coarse granular," but in the southern part it is largely porphyritic and of much less durable quality where much weathered, so that it can be permeated by infiltration of ferruginous water from the overlying lateritic gritty sandstone, and forms an arkose of a reddish colour which is often hard to distinguish from the overlying grit.

At the southern end of the area the granite shows only when the river is low, but as it is followed up northward, it

rises higher and higher in the banks, the overlying grits thinning out progressively, and forms to the E by N. of Virpur a small hill on the right side of the river, which is never submerged, except during phenomenal floods, and which is very favourably suited for the opening of a quarry of this handsome stone. The top of this hill is all but as high as the general level of the country. To the north of the hill the granite sinks again, but the quarriable mass is of great size and well worth consideration.

No accessory minerals were seen in the granite except a few very small inclusions of a dirty whitish-green felspar (oligoclase ?) insufficient in quantity to affect the general colour of the rock.

(*b*) **The Orsang and** (*c*) **Unch river areas.**—The two areas occupied by these rocks in the Sankheda taluq may be for convenience called *Orsang* area and the *Unch river* area, after the two rivers in which the most important outcrops of these old crystalline rocks are met with. The principal inliers are six in number: 1. The *Wadeli inlier* of gneiss including a small but important outcrop of crystalline limestone in the bed of the Orsang river at Wadeli. 2. The *Vidvaswami hill* a small rocky ridge steeply scarped on its eastern side and rising out of the alluvial flat, 2 miles east of Sankheda. 3. A strip of gneissic rocks, the *Deroli inlier,* exposed in the bed of the Unch river in the Thakoreship of Chorangla which is entirely enclosed by Baroda territory. The strip measures $2\frac{3}{4}$ miles in length. 4. A *very small strip,* about a mile in length, or rather a series of small outcrops, in *the bed of the small nullah rising E. of Lachharas* and of its eastern tributary which drains the S. W. end of Lachharas hill. 5. A number of small outcrops, forming a narrow patch half a mile long, on the south or left bank of the Orsang, due south of Bodeli railway station. 6. A rudely circular patch of low whaleback outcrops, about $\frac{1}{2}$ a mile across, around the Bodeli railway station.

Of these areas and inliers, the Orsang area, and the Wadeli inlier, are much the most interesting and important, geologically and economically, and they will therefore be described much more fully than the other crystalline tracts, which have yielded nothing worthy of special note.

The Orsang area.

(*b*) The Orsang area is hard to describe as to its shape which is very irregular. It measures 6½ miles from N. to S. and from 2 to 4½ across from E. to W., and rises but slightly, not more than 40′ or 50′ above the alluvial flat to south and west of it.

The rocks are generally very badly exposed, nearly the whole surface of the country being thickly covered with a great spread of cotton soil. The only good sections to be seen are those in the bed and banks of the Orsang river. A few poor ones are also to be seen in the beds of the Motipura and Harikua nullahs. Outcrops of rock, visible over the surface of the cotton soil, are few and far between.

Section in the Orsang river.

By far the greater part of the rock exposed in the bed and banks of the Orsang is grey or pinkish granite. The granitoid structure is most marked in the southern part of the crystalline tract between Aktiarpura and Allatpura[1] and northward, close up to where the river forms a noisy little rapid. From thence northward, towards Bhulwan, the rock has a more gneissoid structure, due in great measure to lines of fluxion and also to very strongly developed parallel jointing, which gives rise to a semblance to true bedding very likely to deceive any one making only a cursory examination of the rock.

The rock is a true ternary granite made up of grey or pink felspar, quartz and white or black mica. The surface, as a rule, is much weathered, from long continued exposure, but if broken below the weathered crust, the granite is of good quality and would yield itself well to be cut and polished for building and decorative purposes.

A granite, of much better quality than the reddish variety noted opposite to Allatpura, is to be seen in the middle of the stream bed, at low water, to the westward of a very remarkable boss of pure white quartz (to be described further on). This handsome pink granite certainly extends westward out of the river bed somewhere close to Bhulwan village, but the rock seen in the bank has such a deeply weathered surface, that its true colour is very hard to recognize, while the rock in the middle of the bed is com-

1 The name Nurpara appears to be a mistake of the surveyors for the village is absolutely unknown by that name at Sankheda, while the villagers themselves strenuously disown it.

paratively fresh in surface and in parts fairly polished by the river action in the rainy season. This granite is more felspathic than that opposite to Allatpura.

Close to this spot the granite is cut across by a small run of brecciated quartz. As far as can be judged megascopically, the two rocks are completely unchanged on their respective planes of contact.

Rocks seen in Motipura nullah.

Where the Motipura nullah falls into the Orsang, granite crops up and shows for about a furlong northward up the bed of the nullah. Then there is gap of a hundred yards or so, after which gneissic beds show in a cutting which has been made to divert the force of the stream from the local railway bridge. The rocks exposed are extraordinarily weathered and much obscured by an incrustation of highly saline mud, but about the centre of the cutting a somewhat ill-defined bed of rather schisty crystalline limestone occurs, which shows a pale purplish grey colour. A piece of this, which was cut and polished, presents a very lovely colour, and if quarried to sufficient depth, would doubtless furnish a very beautiful marble.

Purplish grey limestone.

In the first stream, flowing into the nullah, from the west is a good show of a handsome pink and pale green granite, which deserves opening up by a quarry.

Limestones south of the bridge.

To the northward of the railway bridge no further trace of any crystalline limestone could be found in the bed of the nullah (in which alone any rock is to be found exposed), although the nullah was very closely prospected for fully two miles further north.[1] To the southward of the bridge, however, where the cotton soil surface has been partly removed, a number of outcrops of crystalline limestone were found by me, on either side of the railway. The railway builders had failed to recognize the true character of the rock exposed in their ballast pits, probably because of the dirty discoloured surfaces presented by the rocks. The beds nearest the railway bridge are cream coloured and grey

1 At the time of my first visit to the Motipura nullah just before Christmas the bed of the nullah contained much water in deep pools, and even at the beginning of February the pools were still very full. It is therefore possible that there may be yet other beds of crystalline limestone to be discovered at the end of the dry season, which are under the water at other times.

purplish limestones, while further south, close to the second culvert, south of the bridge, are grey, greenish white, purple and cinnamon coloured beds on the eastern side of the line, and an important bed of mottled dark green limestone, which alone crops up over the surface of the ubiquitous black soil.

Of these beds, specimens were blasted out, and some polished with very satisfactory results. They yield exceedingly handsome marbles which from their position can be quarried with the greatest ease, and carried into Baroda, quite economically.

Motipura marble bed.

The dark green mottled marble bed can be traced by successive outcrops for more than half a mile from the railway line in a south-westerly direction. Their further extension is hidden by the great cotton soil spread. The beds have a generally south-easterly dip but show much local contortion. It may be that they curve round to the east and are seen again in the nullah bed close to the northern railway bridge near Harikua, where a similar mottled dark green bed is to be seen to the E. of the railway.

Warikua marble beds.

Another set of crystalline limestone, separated from the Motipura set by a spread of black soil, fully half a mile in width, is found in the head water of the northern branch of the Harikua nullah and several outcrops are also to be seen close east of the northern railway bridge at Harikua. To the west of the railway, drab, pale brown and cream, banded with white, are the prevalent colours.

This set of beds had not been opened up by quarrying when I left Baroda, and they will be very important should they prove to be extensive, as they appear to be.

Wadeli marble bed.

Connected with the Motipura beds, is in all probability the pale clouded green marble found in the Wadeli inlier in the bed of Orsang, but half a mile of sandy river bed separates them.

Gneissic beds.

The Archæan rocks, exposed in the bed and banks of the Orsang to the N. W. of the Wadeli marble inlier and above the village of Bhadrali, are very handsome black and white banded rather granitoid gneisses, which make a considerable show in the bed of the river. Here and there the rock is traversed by a vein of yellowish green epidote (pistacite).

Further up the valley of the Orsang close to Dhebarpura the rock seen is a grey micaceous granite-gneiss showing a strike to N. 5°W. and an irregular westerly dip.

The Bodeli inlier.

The Bodeli inlier occupies an area of only about 2—300 acres in extent immediately around the railway terminus and chiefly on its northern side—where a low "whaleback" of coarse, pale pinkish creamy granite had been quarried to a considerable extent—the rock which is a highly felspathic one is too much weathered to be a reliable building stone where exposed to any great pressure. It is cut up by vertical master joints running strictly parallel with a strike of N.E. 10° E.

A small show of granite is to be seen on the leit bank of the Orsang river immediately south of the station, but offers no features of interest.

Gneissic and granitic rocks extend both westward and eastward from the Orsang tract under the alluvial flat but all are exposed only in a few stream sections and offer no points of interest.

The Deroli inlier.

In the Deroli inlier No. 3 there is a great show of grey micaceous gneiss in the bed of the Unch river with a N. S. strike and a dip of from 65° to 70° west, also some red gneiss lower down the river, while micaceous granite gneiss forms the upper half of the exposure in the inlier.

The Unch river area.

c. The rocks forming the Unch river area, in which I include the several exposures in the bed of the river for a couple of miles below Khoria, are chiefly gneisses of grey colour in the western part with more or less northerly strike and westerly dip. About half a mile below Khoria the Unch is crossed by a thick bed of red felsitic gneiss which is cut up by an immense number of joints as well as traversed by many irregular fissures.

The most striking and the most valuable rock in this tract, economically considered, is a dense pale pinkish red gneiss, so highly felspathic as strongly to resemble a felsite. It occurs crossing the nullah which joins the Unch, south of Tandalja about 1½ miles E. S. E. of the villages, but is very ill seen. It greatly resembles the red felstic gneiss below Khoria but is finer grained.

Trap.

Intrusive rocks in the Archæan areas.—The intrusive rocks seen penetrating the granites and gneisses just described are far from numerous—and of no great importance.

Those noted were a pair of trapdykes of very moderate size cutting through the granite at Bodeli. Their courses strike E. by N. and they have risen vertically through the granite and have very sharp cut sides. The trap is a close-grained basaltic (?) mass of dark-black colour. No accessory minerals were observed in it. Both dykes have been largely quarried for road material. There is no evidence of any sort as to the age of these dykes, but their material bears no resemblance to any of the dykes in the Deccan Trap area, seen by me.

Quartz runs.

Quartz intrusions were also noted in the Archæan rocks—the most noteworthy example being a small rocky ridge exposed for a couple of hundred yards close to the right bank of the Unch river, and 2½ miles E. by S. of the great tower in Sankheda fort. The quartz is milky white and of fairly pure character, good enough to be valuable as a material for glass or china manufacture. The run extends apparently northward into the Vidvaswami Mata ridge in which however the quartz loses its purity and good colour.

A very pretty example of a " neck " or small cylindrical intrusion of pure white milky quartz may be seen penetrating the granite in the Orsang river eastward of Motipura Muwara. This neck forms a small but very sharp cut boss, projecting a few feet above the general surface of the surrounding very handsome pink granite, with which it contrasts strongly in colour. The mass exposed measures from 8 to 12 cubic yards.

Brecciated quartz.

Rather further south the granite is traversed by a brecciated run of quartz forming a ridge slightly raised above the general surface. The southern wall of the run which is very well exposed shows a dip of 30°—35° S. by E. The quartz is much less pure than in either of the above named cases. The wall of the run forms a very fairly true plane and there is no evidence of any induced changes along the contact planes.

A few small veins of pegmatite were noticed cutting through the gneisses in the valley of the Unch; they

consist of white quartz and salmon coloured orthoclase with very small spangles of greenish white muscovite (mica).

In the Virpur area.

In the Virpur (Sábarmati) granite area no intrusive rocks were observed within the Gaekwari territory, but at no great distance to the north a few very small E.—W. trap dykes of black basaltic trap cut through the granite, also a fair number of veins of pegmatite of very coarse texture—the felspar being of deep salmon red colour. In some of the veins the felspar is of two colours, a green variety occurring alongside of the red variety. The green one seems to be the source of numerous green pebbles of Amazon stone (orthoclase) found lower down in the bed of the Sábarmati. These have however a more intensely green colour than the mass seen in the veins which have an E.—W. strike and dip, of from 20° to 30° S.

Pegmatite veins with green felspar.

CHAPTER IV.

THE CHAMPANIR SERIES. TRANSITION ROCKS.

The Champanir series is an important group of apparently Azoïc rocks, first correlated and named by Dr. W. T. Blanford, F.R.S., in his memoir on "The Geology of the Tapti and Nerbudda valleys (M. G. S. of I., Vol. VI., p. 202). They constitute a distinctly submetamorphic series of rocks, including quartzites, schists, slates and limestones, which is only met with in the northern and south-eastern parts of Sankheda taluq. In the northern part of the taluq they are seen in several hill ridges, which stretch east to west, close to the boundary between the Gaekwari and the Panchmahal and Narukot territories.

Gugalpur hill.

The first exposure of the Champanirs, met with in the northern parts of the Baroda territory, occurs at Gugalpur, a village 10 miles N. W. of Sankheda. Here the south side of a rocky ridge of quartzite about 1½ miles long belongs to Baroda. The rock has been greatly altered by metamorphism and its bedding is in many places hard to recognize. It seems to represent a deformed anticlinal, of which the southern limb has a very steep (nearly vertical) dip, while the northern limb has a much lower dip to the north. About the centre of the southern side the quartzite is very coarsely conglomeratic, but the deformation has apparently caused such an amount of extra metamorphism that the included shingle can in many cases hardly be distinguished from the matrix. The quartzites are mostly whitish or pale bluish grey much mottled with purplish stains and streaks.

Achali ridge.

The Achali ridge (see p. 4) is formed of a thick series of light coloured quartzites. These two inliers of Champanir rocks are the only ones met with in Baroda territory N. of the Orsang river, but there is a very considerable development of the Champanir series in the Panchmahal to the north and east and west of the two occurrences just named; to the east, the extension of the Achali quartzites, forms the bold and picturesque Mahabar hill.

Inliers in the valley of the Heran.

In the southern and south-eastern parts of the taluq, the Champanir beds form quite a number of small inliers

rising up as small hills through the recent (alluvial and subaerial) formations which are so widely spread over the flat country of the State, or are exposed in the bed and banks of the Heran river. As a glance at the map will show, there are no less than 20 of these small inliers in the valley of the Heran[1] and the greater number of them in the bed and banks of the river.

The arrangement of these numerous inliers may be described as a rudely linear one, the inliers occupying, roughly speaking, three parallel lines which run from W.S.W. to E.N.E. The northern line includes five of them: those of (1) Karali, (2) Partapura, (3) Ghora, and (4 and 5) Lacharras, the latter being two in number. The second or central line includes the inliers close to the banks of, and in the bed of, the Heran, and to it must be reckoned, taking them in order from W.S.W. to E.N.E., the two at Dudhpura, (6 and 7) two small hillocks on the right bank of the river; (8) the Sandara inlier, which extends along the bed of the river for over a mile; (9) the inlier south of Sigam village; (10, 11, 12 and 13) the four inliers at Songir and Indrol; (14) the Padwan inlier; then 3 miles further east, the Lonadra, (15) and (16) the Sihadra inliers. The third line includes (17) the inlier south of the great Songir quarries and (18) the two Kothia hills. Not referable to any of these lines, are the two detached hillocks of Gamri (19) and Chippakua (20), which lie between the western ends of the northern and central lines.

The beds forming these exposures, have in most cases been greatly contorted, and it is not feasible to correlate their position relatively to the beds in the other inliers even approximately; all that can be said with safety, is that the quartzite beds, which form the mass of the three most important of the northern line of inliers, have a south-easterly dip.

The members of the northern line of inliers which may The Karali inlier.

1 Of these several lie within the limits of some of the small Thakurships on the border of or enclosed by Baroda territory, *e.g.*, one in Wasan, two in Dudhpur, one in Wajiria, and two in Wanmala. Of the remainder two are partly in Baroda, partly in adjoining Thakurships. These are the Sandara and Ghora hill inliers. The former of these, which is the most interesting of all geologically and practically, has its north-eastern two-thirds in Baroda territory, while its south-eastern third lies between Wahora and a part of Wajiria.

be taken in order from W. to E. consist mainly of quartzites. In the most westerly (1), the Karali inlier, the rock is extremely altered and very hard to be distinguished from vein quartz. It forms a roughly elliptical mass, the eastern side of which is most largely exposed because of the erosive action of a small stream which has cut a deep gully there. The western side is hidden by the deep loam bed, capped with black soil, which forms the general surface in that neighbourhood. The quartzite beds have been forced up into an almost vertical position with a N. N. W. strike and doubtful dip.

The Partapura inlier.

The Partapura inlier (2) consists of three small hills, of which the principal one runs nearly due W. to E. for half a mile, when the beds forming it leave that course and trend north-easterly. They have a dip of from 55° to 60° S.E. The other two hills run nearly due S. to N. and at right angles to the main hill which they nearly equal in height, rising 70 or 80 feet above the surrounding plain.

The principal beds of rock seen here are quartzites with associated schists. The lowest bed is a grey quartzite, weathering purplish red, the upper beds are brownish and brownish-grey ill-bedded quartzites. The intercalated schists are green (chloritic), grey silvery and drab. There is also a great show of variegated argillite schists in hightly contorted beds in the bed of the nullah flowing south of Partapura village. A few quartz veins occur among the schists, the largest of which occurs close to the chloritic schist and looks rather promising for gold, for which it deserves to be tested.

A small outcrop, of an utterly decomposed trap rock, is to be seen in the nullah banks above (east of) the argillite schists first referred to. Whether it belongs to the Champanir system or not, could not be decided, as it does not show any actual contact with the old rocks. In its general appearance it greatly resembles some of the friable decomposed beds in the Deccan trap, of which it might possibly be a small remnant. If so, it must have flowed on to the surface of the Champanir rocks after the once superincumbent Bagh beds has been denuded away.

Ghora hill inlier.

Ghora hill (3) is a rather bare ridge running near E.N.E. and doubtless an extension of the quartzite and schist

beds exposed at the northern end of the Partapura hill. The west end of the ridge shows a phenomenal amount of brecciation of the quartzite which has been extra-metamorphosed, doubtless during the deformation of the strata, by compression. The brecciation is rendered the more apparent owing to the formation of films of specular iron on the fracture surfaces. Even where this iron staining does not occur, the results of the crushing undergone are very strikingly seen. The ridge consists of two very distinct quartzite beds separated by a purplish grey, slightly feruginous, shaley schist. The strike coincides with the axis of the ridge and is very distinct, but not so the dip which forms a high angle to the S.S.E.

Lâchharas hill.

The fourth inlier (4) Lâchharas hill is the largest and second highest hill in Sankheda taluq, and consists entirely of whitish, bluish white or grey flaggy quartzites which frequently show very well preserved ripple markings and, in parts, a good deal of contortion.

The hill forms a rounded, rather flat-topped, mass with a gentle slope to the S.E., but shows a rather abrupt scarp to the N. and N.W. The view from the top, which has an elevation of 508′ above sea-level, and of about 280′ above the surrounding country, forms a very fine panorama particularly to the north and south with Pavagad and the Rajpipla hills, respectively, in the background. To the E. also the bold slopes of Phenai Mata hill in Chota Udepur State are very pleasing to the eye. The country generally, however, is too thickly wooded to make the view a geologically instructive one.

The beds forming the hill, trend from E. by N. (with a dip of 60°—70° S. by E. at the trigonometrical station, at the east end,) to due N. and S. at the southern end where also they show much deformation and many variable dips.

The base of the quartzites is not exposed along the northern scarp, but about 300 yards from the visible western boundary of the Champanirs decomposed micaceous gneiss is exposed in the bed of the stream flowing from the hill.

In the little quartzite hill showing N.W. of the main hill, the quartzites apparently dip under those of the main hill at angles of 25°—30 S. E. by S., and if so,

the total thickness of the beds must amount to several hundred feet, but it cannot be actually measured.

Inlier No. 5. South of the south end of the Lachharas hill inlier is a small rocky ridge of much contorted quartzite, (inlier No. 5,) ranging in strike and dip from N. to S. vertical, to S.W. with a dip of from 30° to 40°, which latter is clearly a case of inversion of the beds.

No correlation of beds in this northern line of inliers with those lying south of it can be attempted at present, owing to the distance separating the several outcrops and the great amount of crumpling the whole series has undergone.

Dudhpura inliers. Of the inliers of the second, or central line the two most westerly (6 and 7) are low bare rocky hillocks of greatly altered quartzite occurring, the one S. S. W. and other, N. N. E. of Dudhpura, on the right bank of the Heran. The southern one of the two stands 201′ above sea-level, but only 20 or 30 feet above the surrounding country. In both cases the bedding of the whitish quartzite is decidedly obscure. The southern hillock lies just 3 miles S. of the Partapura main hill.

Sandara inlier. Great series of marble beds. Next in easterly succession, is the important inlier of Sandara, which occupies a couple of reaches in the Heran river. I call it the Sandara inlier from the little Gaekwari village of that name lying close to the north side of its centre on the right bank of the river. Sandara is exactly 7 miles S. by E. of the trigonometrical station on the tower of the old fort at Sankheda.

The south-western part of the inlier lies in the Virampara reach of the river, and is not in Gaekwari territory, which begins however in the next short reach just south of Sandara village.

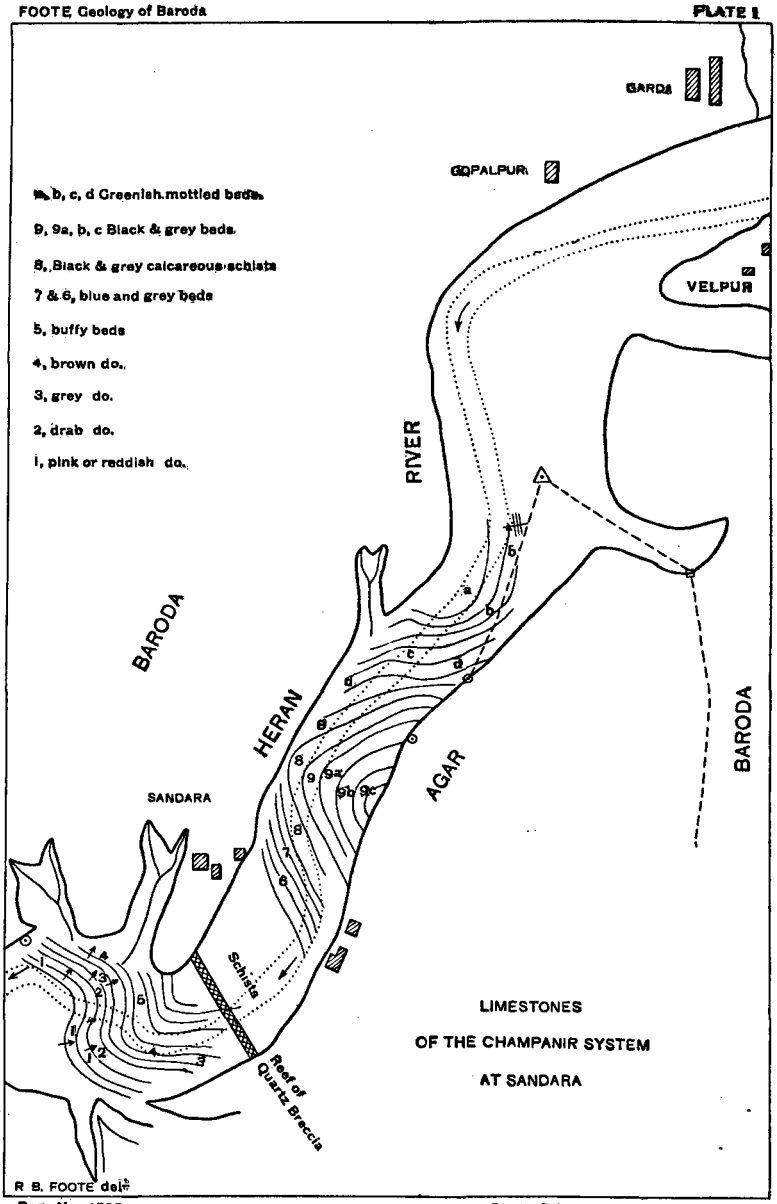
At the northern extremity of the Sandara north reach the marble beds disappear under the modern alluvium and are not seen again, and what member of the Champanir series may overlie them is at present not known.

The distribution of the limestone and schist beds in the two reaches of the Heran at Sandara[1], will be best under-

1 According to the map (Topo. sheet $\frac{15}{44}$) the Gaekwari boundary of the eastern Sandara reach lies along the left bank of the river, and if this be correct, which I believe, the whole of the marble beds there exposed belong to Baroda.

FOOTE Geology of Baroda

PLATE I



Reg: No. 4793
Copies. 310

Photo-Print., Survey Office, Madras.
1899

stood from the small map annexed, on which I have laid down their relative positions. (Plate I.)

The south-western end of the inlier is occupied by schists which show on the left bank of the river quite close to the eastern end of Wahora. Just south of Virampara, on the opposite bank, the river is crossed by a strong outcrop of coarse gneissoid micaceo-siliceous schist which runs nearly N. W. by W. with a dip of 80° N. E. by E. The outcrop makes a strong reef broken through only in the centre, where the main current of the river flows.

Above this, for about half a mile, the bed of the river is occupied by micaceous and calcareous schists which are wildly contorted and much broken in their flexures. Following these, and probably overlying them, comes an important series of limestones (marbles) both thin and thick-flagged, with a high northerly dip and striking nearly W. N. W.

The lower beds of these are pinkish and drab, followed upwards by banded grey brown and buff. In the centre of the reach these beds are seen to bend round south and then to trend eastward, the result being in plan a great and almost sigmoid double curve.

In the centre, between the two curves, the beds show much crushing and have been converted into a coarse breccia of very handsome appearance, especially in the reddish and warm buff coloured beds. Unfortunately the extent of the brecciation is but small, for where it occurs the result is a breccia marble of very great beauty. Brecciated beds.

The limestone, where unbrecciated, is very dense and a most valuable stone for building and decorative purposes, and the greater part of the beds seen in the river bed lie within the Baroda boundary. The western extremities of the beds disappear under the loam formation of the right river bank into which they could easily be followed, when a sufficient demand for them arises.

Some beautiful specimens of rock curving are to be seen in the contorted beds south of the little waterfall in the river. They are on so small a scale that they show well in blocks of very moderate size. Several such were secured for the Museum. Curved bedding.

These limestones, of the Sandara south reach, dip under

a series of green and brown schists through which runs a medium-sized reef of brecciated quartz immediately south of Sandara village. The schists extend northward for about ¼ of a mile along the reach of the Heran N. E. of Sandara. They are followed by thick bedded blue grey limestone which weathers dark brown and occurs in considerable quantity. Overlying this is a thick series of dark grey, almost black, calcareous schists which are much disturbed and contorted and in parts, cleaved. They are overlaid by beds of black limestones with white veins of calcite forming a marble of great beauty if sufficiently hard to take a high polish.

Blue grey marble.

Black and white marble beds.

Greenish marbles.

North of the black and white marble area which covers a considerable space and extends clean across the bed of the river, comes in a great thickness of greenish white and greyish green, sub-crystalline limestone both mottled and clouded, and of great beauty. There are two very distinct bands of this green rock, which is but little cut up by jointing and hence could yield large blocks if properly quarried. Much of the beds lies right in the shallow broad bed of the river and would therefore be less easily accessible than the other beds lower down where the medium channel has been cut to a much greater depth, so that the sides of the river would be submerged only during floods.

Unless these green beds represent the grey and brown ones underlying the black limestone and calcareous schists with which they certainly appear to correspond in position, they must belong to some other part of the series and have been brought into their present position by great faulting and dislocation. Of this I could see no evidence, but the change in colour is so great as to be a striking phenomenon which calls for explanation.

In the most northerly outcrop of the green beds, I noticed a very small and ill-defined vein of calcite with pale pink orthoclase, in ill-defined crystals.

Beyond this point the limestone series is hidden by the sand and shingle banks in the bed of the river, and no connection can be traced between it and the white crystalline limestone bed to be mentioned further on as occurring in the Sigam inlier.

Sigam inlier.

Rather more than half a mile above the northern end of

the Sandara inlier, lies the Sigam inlier (No. 9), in the bed of the Heran south of the little village of Sigam. In this inlier nothing is seen but a variety of schists and a solitary small bed of excessively coarse dirty white crystalline limestone, a calcite rock in fact, the surface of which has been much injured by the action of the river water. On blasting, this limestone proved to be of poor quality owing to its coarse irregular grain. In colour it is mottled with brown and is by no means a good-looking stone. The schists on the south, and in the centre of the deep water channel in the river, are mostly light brown in colour. Many of them show a speckling of a darker brown reminding one somewhat of the speckling on the plumage of a partridge. The schists show very great cleavage which has in most places entirely obliterated the true bedding of the rocks. The cleavage planes run N. by W. to S. by E. and have a dip of from 80°—85° N. by S.

Chloritic schists with auriferous quartz veins.

On the north side of the river, is a considerable thickness of chloritic schist, which forms quite a distinct knoll under the loam of the right banks and rises very nearly to the general surface of the country. In this schist are a couple of small quartz veins the surface of which shows many cavities due to the weathering out of some accessory mineral, doubtless calcite. In some pieces obtained from some little depth below the present surface, the cavities were filled with chlorite, but this must be regarded as pseudomorphic.

Assay of the quartz.

The quartz of these veins was assayed by Mr. Grey of the Urigam Mine, Kolar Gold Field, Mysore, and found to be slightly auriferous. The results of the assays which are given in the chapter on Economic Geology (Chapter IX.) were not sufficiently encouraging to make me recommend the veins being "prospected" in depth as they are of small size and length. The quartz filled with cavities is a typical example of what the Australian gold miners call "mouse-eaten" quartz. No traces of pyrites were noticed in the stone which is of a milky white colour.

Sigam Kanbi inlier.

In the next eastward inlier (10) lying south of the hamlet of Sigam Kanbi ⅔ of a mile N. E. by E. of Sigam village are well-bedded quartzites which have a dip of some 30° southward but also roll somewhat. Intercalated in them is a quartz vein occupying very much the position

of a flow, from the low angle at which it lies among the quartzites. These latter are undoubtedly of Champanir age and apparently overlie the thick mass of schists forming the inlier occurring in the bed of the Songir reach of the Heran river.

River bed inlier at Songir.

The Songir river bed inlier (11) shows nothing but schists of various colours, *e.g.*, brown, brown speckled, grey, greenish, pinkish, purplish and silvery (micaceous) of many shades. The strike is normal to the axis of the inlier, namely about W. S. W. to E. N. E. The dip is generally doubtful, but a distinctly exposed one at the W. end of the inlier measured 80° S. S. E. The relation of these schists beds to the quartzite in inlier No. 10 south of Sigam Kanbi hamlet is doubtful.

Inliers N. of the Songir ridge.

In the two inliers (12 and 13) seen underlying the base of the Bagh rocks, north of the great Songir sandstone quarries, the rocks exposed are schists and slates which in the western part are mostly purple in colour and have a strike to the N. W. by N. with a high westerly dip. The unconformity between these slatey rocks and the overlying gritty Bagh sandstones is very marked indeed and shows conclusively, that the Champanir rocks had been greatly upheaved and deformed and subsequently eroded, and this prior to the deposition of the Bagh series. The bedding and cleavage of these slates appears to coincide, but the latter is not sufficiently strong to make the stone as fissile as is required for the preparation of proper roofing slates, though in point of hardness and fineness of grain it is but little wanting. The colour is a distinct warm purple and the stone might be used for tilestones or small flagging stones. The other outcrops of slate examined were of greatly inferior quality and really useless. This is markedly the case at the eastern end of the inlier.

The eastern inlier at Songir.

At its N. E. end the inlier widens out very greatly and extends right across the bed of the river. Two round topped knolls show one on each side of the river, and are formed of much altered quartzite greatly comminuted by excessive jointing. Their relation to the schists is not at all clearly seen.

The Padwan inlier.

A quarter mile E. of this inlier (No. 13), commences another which is similarly only exposed in the bed of the

Heran and which may well be called the Padwan inlier. It consists of quartzite sandstones, often micaceous, and of drab colour. At the eastern end is a very interesting section showing a very good and striking example of the great unconformity subsisting between the Champanirs and Bagh beds close by. As will be seen by the map, the Bagh beds (Songir sandstones and basement conglomerates) form a curved barrier across the Heran, like a great masonry dam. In the southern half of the curve the Champanir beds, locally micaceous quartzite sandstones, are seen lying unconformably under the Bagh conglomerates which rest on the highly upturned basset edges of the quartzites. The latter dip 55° S. W. by W., while the former have a southerly and south-easterly dip of from 3° to 8°. A very small outlier of the Baghs has by the erosive action of the river been cut away from the main mass and rests most strikingly on the upturned Champanirs. It is one of the prettiest examples of stratigraphical discordance on a small scale, I have ever seen, and well worthy of photographic illustration. The contrast between the fine grained, ripple-marked, well-bedded, drab, micaceous quartzite-sandstone and the coarse greyish brown pebble bed forming the base of the Songir series locally, is very strong.

The Lonadra inlier.

Two and a half miles higher up the river another inlier, (15) the Lonadra inlier of Champanir slates and schists occurs on the south bank, and extends for $\frac{2}{3}$ of a mile eastward close up to the village of Lonadra[1]. The beds seen are purple, grey or brownish purple in colour and some of them distinctly slatey in character and fairly cleavable but cut up by a system of jointing into narrow strips only from 3 to 4 inches wide and from 10 to 15 inches long. They could be used only for tilestones and not well as such. The beds roll about a good deal but have a general dip westward.

The Sihadra inlier.

A quarter of a mile east of this Lonadra inlier is the Sihadra inlier (16) consisting of two small knolls of quartzite rather whale-backed in shape. On the eastern knoll the rock is white and grey and rolls about at very low angles. On the western some of the beds are very thin flagged,

1 Indicated but not named on the 1-inch map (sheet $\frac{44}{15 \cdot 5}$).

some less than an inch in thickness, and these are quarried to a small extent to be used as baking plates and are also locally used as whetsones.

The northern boundary of this inlier is formed by the great black soil spread which covers the great Gujarat alluvial series everywhere in the Heran valley. To the south the Champanirs dip under standstones of Bagh age of which there is a considerable show in the bed and banks of the Kurwa Naddi, a little river falling into the Heran at Lonadra. The grey quartzites at the Lonadra, or western end of the inlier, form quite a sharp cut little ridge. The beds roll about a good deal, but the general dip is about S. E. by S. at an angle of 60°. The Sihadra inlier is the last of the central line of Champanir inliers in the Heran valley.

The third line of inliers.

A third short line of inliers occurs to the south of the central and part of the second line and immediately south of the Songir quarry hill. The inliers in this line are two in number (Nos. 17 and 18) and of considerable size relatively to the other numbers of the series. Both lie in the Wanmala thakurship.

The Punpawa Mata inlier.

The more westerly of the two (17) occupies three sides of the lower scarp of the Punpawa Mata hill, the upper scarp of the hill being formed by an overlying mass of Bagh beds, southerly extensions of the Songir sandstones and basement conglomerates occurring only a quarter of a mile to the N. The latter beds are faulted against Champanir beds, but the actual fault is masked by a tongue of alluvium stretching up from the great spread to the eastward. The surface of the inlier is to a very great extent concealed by thick tree jungle, and still more so by the great quantity of talus fallen from the overlying Bagh sandstones and conglomerate beds. The northern spur is not quite so thickly covered by the fallen blocks and the Champanirs can here be seen to consist of typical quartzites rolling E. at a probable average angle of 40°—45°. The western end of the inlier is also much obscured by jungle and fallen Bagh sandstone debris. Outcrops of micaceous schist were noticed here in a greatly weathered condition.

The Kothia hills inlier.

The eastern inlier consists of quartzites, forming three small jungly hills rising about 150′ above the general flat

to the E. The bedding is obscure and rolls a good deal, and the inlier is on the whole remarkably uninteresting.

The remaining two inliers of the 20 named at page 30, are of very small size and of too trifling importance to be reckoned as forming a distinct line of inliers. Their position is between the western ends of the northern and central lines of inliers. Both form little hills of nearly bare rock. The most westerly, Gamri hillock (19), is a low narrow ridge about 200 yards long with obscure bedding having a southerly dip, the quartzite is much altered and quartzified and greatly weather worn as well. The last of all the inliers is the small Chippakui hill lying 1¼ mile W. N. W. of Sandara and rising about 60 feet above the cotton soil plain around. Its northern side is scarped into a bare rocky cliff. The quartzites, which contain a fair number of small quartz veins, have a southerly dip of about 30°. Inliers 19 and 20.

No traces of the Champanir beds were found in any part of the Gaekwari except the Sankheda taluq.

Perfectly detached from the series of inliers just enumerated, but lying across the road from Sankheda to the outlying tappa of Amroli, are three small inliers of Champanir rocks which rise as small hills out of the general alluvial flat just south of the Thakur village of Naswari. The westernmost of these is much the most important. It rises fully 200 feet, or more, over the valley of the Aswan river. The eastern part of the hill and the lower part of the northern scarp of the western end, consists of typical Champanir quartzites, which have a N. by W. strike and a W. by S. dip at an angle of from 60° to 70°. The other two inliers are of similar quartzite but are much less important in size in every way. They are exposed by the denudation of the overlying Bagh sandstones. Inliers at Naswari.

Not quite half a mile south of the hamlet of Sandia, (Kundia of the Topo. sheet $\frac{184}{44}$) on the left bank of the Heran river is a line of craggy rocks some 25 to 30 feet high towering picturesquely over the alluvial flat. These rocks consist of a very typical breccia of a porcellanous jaspery quartzite of varying colours, the matrix being sometimes reddish and the brecciated fragments whitish or *vice versâ*. The stone is one of great beauty. Sandia. Breccia rocks.

CHAPTER V.

THE BAGH BEDS (MARINE CRETACEOUS SERIES).

Rocks referable to this group have been found only in the central division of the State, the Baroda Prant, and were met with in the southern parts of the Sankheda, and along the eastern boundaries of Waghoria and Sauli taluqs.

In Sankheda Taluq :—

These rocks which are of limited extent, taking only the fifth place in extent of the area occupied by them, occur chiefly in Sankheda taluq and are very well known through their principal representative, the famous Songir sandstone, one of the finest and best building stones in Gujarat.

In the Heran valley.

In Sankheda taluq the Bagh beds occur in the valley of the Men river, in the outlying Amroli mahal, and in the valley of the Heran river. South of the Heran valley they occur in four inliers, standing up from among the recent deposits. In similar position are the three small inliers occurring on the N. side of the valley to the S. and S. E. of the Lachharas quartzite hill.

In the Men valley.

The Bagh rocks in the Amroli mahal are represented in four distinct inliers. The principal of these, forms a low narrow band south of Baroli, rising here and there as a low ridge a few feet only above the nearly dead flat of the country and running 5½ miles E. by 5° N. with a width of from a few yards to $\frac{3}{5}$ of a mile. The rocks here seen are whitish, drab and brownish pink sandstones dipping southward at from 35° to 40°.

Two small inliers of sandstones, in part pebbly, are to be seen in the bed of the Men river above and below the village of Kankuvasan. They dip respectively 10° and 15°—20° S. S. E. and are overlaid by the Deccan Trap. They offer no points of special interest. The fourth of the Bagh inliers in the Amroli mahal lies immediately north of the detached village of Nawagám 4 miles E. by N. of Amroli itself and forms a very trifling rise about a mile long and 2/5ths of a mile across at its widest point. The rocks seen are sandstones of the ordinary type, but on them

lay a few blocks of a very earthy dirty brown limestone with a few small oystershells and obscure vegetable markings. The surface is much covered up by cotton soil and but little of the sandstone is to be seen.

The Songir inlier.

Of the group of inliers in the valley of the Heran, the most interesting and important one, is the mostly westerly, in the central part of which lie the famous quarries of Songir[1] which have for a very long period supplied valuable building stone to this region. The whole of this inlier is hilly, being occupied by a considerable thickness of sandstone and grit resting on pebbly conglomerate beds, forming the base of the series and resting, with marked unconformity, on the underlying slates and schists of the Champanir series.

The sandstones which have been, and are now still, quarried in a most unsystematic and wasteful manner have on the whole a southerly dip at low but variable angles.

In the western part of the quarry area, which is extensive, whitish stone predominates and has been largely quarried in former years. In the central part reddish or brownish rather gritty beds were being quarried at the time of my visits at the end of 1891 and early in 1892. Many of the gritty beds are brown or even purplish in colour and thin bedded, and these are quarried largely for the purpose of making hand millstones in which there is a considerable trade (see Chapter IX.) The thickbedded sandstones were neglected to a great extent. Many of these show fine examples of diagonal bedding, "false bedding" so called. These are very conspicuous from the presence of many laminæ of purplish or reddish brown or blackish grains which contrast markedly with the creamy, drab, or whitish general mass of the rock. The changes of current, direction, and of the material carried, were very numerous and give the stone a very handsome appearance in many cases.

In the centre of the quarry area the beds are nearly horizontal or roll about slightly at very low angles. The surface of the rock is so much obscured by waste heaps and

1 The quarries take their name from the little hamlet of Songir lying about ¾ mile N. N. W. on the right bank of the Heran river. They are often ignorantly called the "Songad" quarries, but that is quite a misnomer and leads to confusion, the true "Songad" being a fortified hill in the Deccan trap region 50 miles E. of Surat.

jungle that I failed to form any satisfactory estimate of the thickness of the sandstone series here exposed, but it is certainly very considerable. Remarks on the system, or rather utter want of system, in the quarrying work will be found in Chapter IX.

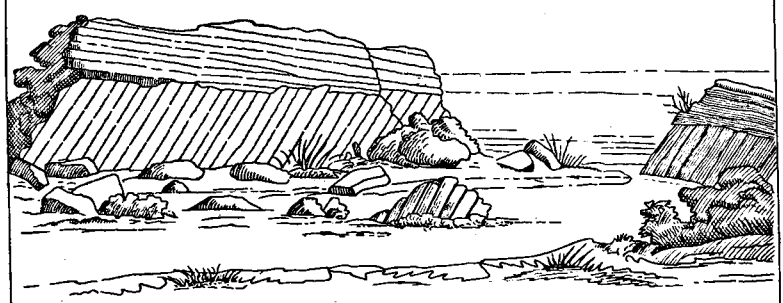
The Ghantoli inlier.

The second inlier to be noticed is that of Ghantoli which lies immediately E. of the east end of the Songir area, separated from it by only a narrow belt of the alluvium and forms a long narrow ridge, the western half of which is a low jungle covered hill, the eastern a mere low rise partly cultivated, partly covered with scrub. It is entirely formed of coarse gritty and pebbly beds with a low southerly dip.

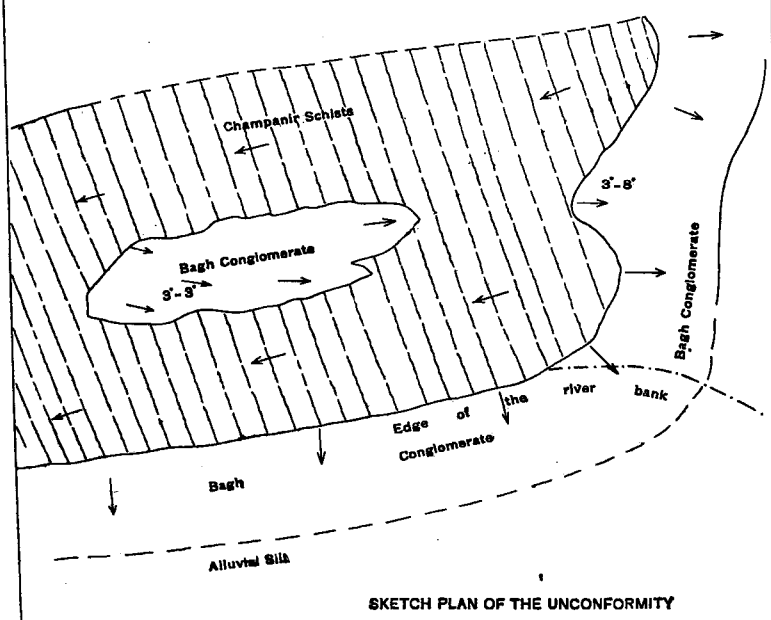
At Ghantoli the basement gritty and pebbly beds trend rapidly N. E. across the Heran river, forming a quay or low flat weir which appears to have been broken through at its centre but recently. Below the "weir" the river is very narrow and has a rocky channel and violent current, but above it the channel is wide and sandy without any trace of rock visible for about 3 miles. Just below the southern end of the quay, or weir, is the pretty section described above (p. 38) in which the great unconformity of the Bagh beds to the underlying Champanirs is so strikingly exhibited. The annexed diagrammatic sketch (Plate II) explains the relative position of the respective rocks very clearly. The quay is actually formed by the basal conglomeratic grit of the Baghs which dips south and trends to S. E. about the middle of the quay, the dip being generally but 3^0, but here and there increasing to 8^0.

The Waterahed inlier.

The third inlier forms the main mass of the Baghs in the Heran valley. It forms a low rise varying in breadth from 500 yards near the western end, to 2 miles a little W. of its eastern extremity and measuring about 9 miles in length, of which 6 lie in the Gaekwari. Its rise above the general flat near the river is not great, and moreover the rise is so gentle that it is far from easy to estimate it. The back of the rise is nearly everywhere covered with small tree jungle, much of it being teak. Between the trees are numerous exposures of grits and conglomerate showing flat, or gently rolling, beds. A characteristic of the conglomerates is the large number of



Unconformity of the Bagh and Champanir beds, as seen in the bed of Heran River at Ghantoli
(Diagrammatic)



SKETCH PLAN OF THE UNCONFORMITY

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small pebbles of bright red jasper they include; the great bulk of the included pebbles consists of quartz, white, reddish white, or grey in colour. The bed surfaces are much discoloured, locally, by a black lichen growing on the sandy matrix between the pebbles.

Much cotton soil occurs on the rise and hides the rocks over large tracts; this is specially the case in the eastern part of the rise.

Taken as a whole, the rise appears to be the back of a broad and very flat anticlinal roll of the sandstone series. At its western end the beds seen are pinkish grey or dirty pale purplish, hard, gritty sandstone approaching quartzite in density. To the S. W. of Parwata (Parwanta of Topo. sheet $\frac{44}{184}$) is a great show of massive sandstone of good quality, which appears to be a continuation of the Songir quarry beds and to be overlaid, further east, by the jasper-bearing pebble beds—a representative of which occurs overlying the quarry beds at Songir itself.

The Kurwa Naddi section.

The only exposure of the rocks in this inlier, that in any way deserves the name of a section, occurs at its N. E. end in the little Kurwa Naddi. This section lies about $\frac{3}{4}$ of a mile S. E. by E. of Sihadra, close to where a road running S. E. crosses the stream. Proceeding up the stream the following section is met with above the crossing of the road leading from Wasna to Baghliwao :—

7. Calcareous grit, fine reddish.
6. Argillo-calcareous sandstone, purplish, thin bedded.
   gap.
5. Argillo-calcareous shales, purple.
   gap.
4. Sandstone, rather coarse, false bedded.
3. Clay, gritty, purple.
2. Clay, gritty, red purple.
1. Sandstone, whitish, false bedded.
   Base hidden by water and local alluvium.

The general dip of the beds is from 15° to 20°. The section is a poor shallow one, only seen in the river bed and much obscured by superficial deposits and especially by cotton soil.

Further west down the stream are many small outcrops of sandstone and conglomerate whose relation to each other is not to be made out satisfactorily because they are insufficiently exposed. The probability, however, is that they are frequent repetitions of the same beds which roll about gently. They extend at intervals all down the bed of the nullah.

A few score yards outside the eastern boundary of the state, the sandstone series appears to be overlaid by a band of very gritty limestone passing into calcareous grit in which I detected obscure traces of shells. The upper beds of the limestone are full of chert and clayey matter. In colour the limestone ranges from lavender grey to reddish brown. They doubtless extend W. S. W. into the Gaekwari territory, but are there completely hidden by a great thickness of swampy black soil which also prevents the contact of the sandstones and limestones being seen.

About a mile to the south-west of the Kherwa Naddi section, on the crest of the low rise, forming the watershed between the Naddi and the valley of the Aswan river, where the cotton soil is much thinner, are small outcrops of the Songir sandstones and grits showing among the thin teakwood jungle which occurs here. These are extensions of the beds seen further west and described above. At the extreme east end of the rise, close to the State boundary, the surface is 300 feet above sea-level.

The three inliers at Lachharas.

Of the three inliers of the Bagh series on the north side of the Heran valley mentioned at page 41, the central and largest one only merits more than mere mention. It is an irregular shaped tract $1\frac{1}{5}$ mile long, varying in width from a little less than half a mile to rather less than a quarter. Its western end lies in the village of Lachharas and its axis coincides with the course of the stream flowing through the village from the N.E. by E.

In the banks of the stream the sandstones are fairly exposed in small cliffy scarps. Externally they are brown; but on fracture drab, or buffy, in colour. They have a general southerly dip of from 10° to 15°. The bed of the stream, in its lower course, near the village forms a shallow cañon in the southern side of which some very fine beds of hard sandstone are exposed which look fit to be

quarried for large millstones, if only hard enough. A very large quantity of stone is available here when the Songir supply may become exhausted hereafter.

No traces of the Bagh rocks were met with in the valley of the Orsang and its tributaries in the northern part of Sankheda taluq.

In Waghoria Taluq :—

The Dev river inlier.

Only one outcrop of the lower cretaceous rocks was here found occurring in a small inlier exposed in the bed of the Deo (Dev), only when the river is low, for about 300 yards. This occurs at Jaipur, a small hamlet (not named in Topo. sheet No. $\frac{29}{15 1}$) 2½ miles E. by S. from Waghoria itself. The rocks here seen are rather soft reddish and buffy sandstones, which are underlaid by a dark greyish mottled calcareous sandstone of harder character. The rocks are rolling gently and are much cut up by parallel jointing. The reddish beds strongly resemble the reddish calcareous grit on the bank of the Kurwa Naddi above described (p. 44). Slight traces of fossil shells were noticed in the buffy sandstone.

No use appears to be made of these sandstones, though they are of sufficiently good quality to be worth quarrying.

In the Sauli Taluq :—

The Dhantaj inliers.

In the valley of the Karad river, to the E. S. E. of Dhantaj, is an important, though small, inlier of the Baghs, which underlie the basement of the Deccan trap, there formed by a basaltic flow. The Baghs are exposed only in the bed and banks of the river along which they extend for a distance of two miles from the bend of the river at the west end of the Bhaga reach. They consist of gritty calcareous sandstones, passing into pebbly gritty limestones. The bedding is very contorted and the beds themselves of great thickness. A westerly dip is however distinctly discernible in parts.

Irregular bands and strings of chert are common in the calcareous beds, and often spoil them as building stones; still, by good quarrying much valuable stone might be raised.

The colours of the rocks are grey mottled with white or drab, occasionally reddish from the presence of lateritoid concretionary inclusions. The chert bands are mostly mottled white and reddish in colour and occur of considerable size, but are externally so greatly comminuted by

numerous cracks as to be worthless for practical purposes, but in the interior of the great masses the chert may very probably be in quite continuous masses, in which case handsomely coloured pieces would be of some value for decorative purposes.

The eastern half of the inlier extends from the Gaekwari into an outlying bit of the Halol taluq (Panch Mahals).

The western inlier.

Half a mile down the Karad river below Dhantaj, is another small inlier rising through the trap rocks, which must have, been poured out over the rugged subaerially denuded surface of these lower cretaceous rocks.

The inlier is composed of calcareous sandstones very similar in character to those above Dhantaj. The beds are very massive and mostly of mottled grey colour and contain many laminæ and lenticular segregation masses of chert, much of which is of handsome bluish white colour mottled with red. The inlier measures about 300 yards in length from S. E. to N. W. by 200 in width.

The Sándásál inliers.

Nearly 3 miles N. N. W. of the Dhantaj inlier in the Karad river three more small inliers of Bagh rocks are exposed in the bed of the Goma river, close to the small town of Sándásál. The beds here seen are very generally like those seen in the Karad river, namely, thickbedded calcareous gritty sandstones mottled white or drab and yellow.

Near the centre of the largest of the three inliers, a very fine bed of pebbly conglomerate occurs, parts of which are very striking in appearance owing to the presence of numerous pebbles of bright red jasper. This "pudding-stone" is both over and underlaid by massive beds of mottled gritty calcareous sandstone, some of which are suitable for building material. Concretionary structure is commonly seen in the lower beds. A large mass of such sandstone forms a small temple crowned island immediately S. W. of Sándásál town, and this island constitutes the second inlier.

As in the case of the calcareous grits at Dhantaj many cherty bands and segregations are seen in the calcareous grits at Sándásál; the chert ranges from white to red in colour. There is a good deal of difference in the degree of induration shown by several of the sandstones, some being rather friable, but others quite sufficiently hard to be worth quarrying.

A quarter of a mile below the town of Sándásál lies the third of the Bagh bed inliers in the same valley. The rocks forming it are mottled greyish calcareous massive sandstones. At the western end of the inlier, immediately east of the village of Dipapura, the sandstone, locally chert banded, forms a small cliff in which the bedding is seen with unusual distinctness and shows a dip of from 30°—40° S. W. No sign of the Deccan trap is seen along with the Sándásál inlier. The alluvium evidently rests directly on a cleanly exposed surface of the marine cretaceous series, the once overlying trap having been entirely removed by denudation.

The Karáchhla inlier.

Rather more than 4 miles N. N. W. of Sándásál, Bagh beds are again met with in a small inlier cropping out from under the Deccan trap in the bed of the Mesri river at the village of Karáchhla. The inlier which lies S. and S. W. of the villages is only ¼ mile long and about 300 yards wide, and the rocks exposed are not seen continuously, but in stray ledges and blocks peeping up through the sandy river bed. The southern part of the inlier is obscured by overlying alluvium. The rocks which here represent the Bagh series are pebbly calcareous, pinkish, drab and pale brown sandstones with an apparently easterly dip.

The Kun river inlier.

The last of the exposures of the Bagh rocks seen in the Sauli taluq, occurs in the south (left) bank and the bed of the Kun river, a tributary of the Mahi, from the east, where it forms an inlier a little more than 2 miles E. of the low level railway bridge over the Mahi at Pali. The Bagh beds are here surrounded by the overlying Deccan trap on the S. and by the river alluvium to the N. and E. Only the southern part of the inlier lies within the Gaekwari limits, the northern and eastern part belongs to the collectorate of Godhra in the Panch Mahals. The small town of Timba stands immediately north of the inlier on the north bank of the river.

The rocks seen here are gritty limestones with standstones and pebbly beds which in their general appearance and colours, (*e.g.* purplish grey and pale pinkish, and whitish brown or drab) strongly resemble the rocks described above at Jaipur, Dhantaj and Sándásál. The rocks seen in this inlier which I will call the "Kun river inlier" are, as a rule, obscurely bedded, but the dip where visible is mostly to the S. W.

They are fairly well indurated but do not seem to be quarried for building purposes, though of quite sufficiently good quality.

Fossils.

Except for the small oyster shells in limestone blocks at Nawagam near Amroli (p. 43) and for the obscure traces of shells seen in the gritty limestone on the banks of the Kurwa Naddi (Sankheda taluq) described at page 44 and the calcareous sandstone from Jaipur (in Waghoria taluq), no organic remains were observed by me, but some members of the series may nevertheless be fossiliferous here and there, for the time at my disposal did not allow of any close search for fossils.

Infraposition to the Deccan trap.

The stratigraphical position of these beds is quite clear, for eir infraposition to the Deccan trap is distinctly seen in no less than four of the Bagh areas now described, namely, in the watershed inlier south of the Heran river, in the Dhantaj (Karad river), Karáchhla (Mesri river), and Kun river inliers. They had been considerably disturbed and upheaved, and then denuded, prior to the time when the basement flows of the great trap series were poured out over them.

CHAPTER VI.

THE DECCAN TRAP SERIES.

The volcanic formations, which make up this great series of rocks of upper cretaceous age, occupy the largest portion of the Baroda country not covered by recent deposits, and lie mainly in the Nausari Prant, the trappean areas in the Baroda and Kari Prants being of comparatively very trifling extent. They will be described in succession from N. to S. beginning with those seen in the Dehgam taluq.

A. In the Dehgam Taluq :—

Trap rocks in the Wátrak river and its tributaries.

The most northerly point at which these trappean rocks are known to occur in the Baroda territory, is the valley of the Wátrak river, at the northern end of the Átarsumba division of Dehgam taluq. To the eastward of that river, indications of their existence below the general surface of the recent beds are obtained from a few well sections and a solitary natural exposure in the bed of the little Dhámni river.

The rising ground, between the Dhámni and Mohár rivers, in the extreme eastern corner of the Átarsumba subdivision is formed of trap—chiefly a basalt—much hidden by black soil. Southward of this trap area are various small shows of trap rock in the bed and banks of the Mohar river, associated with several very small but interesting inliers of intertrappean limestones and sandstones which will be referred to again further on. Further down the Mohar river, at and below, Waráli, and to the south of it, and in the northern part of the outlying village of Garod, are many outcrops of basaltic trap with occasional intercalations of ashy beds.

To return to the trap sections in the Wátrak river, to the north and west of the Thakuri village of Mandwa. They present no features of any special interest consisting as they do only of basaltic flows with associated tufaceous and amygdaloid beds. No great thickness is exposed as the flows are fairly level. West of Mandwa the trap

is covered up by the river alluvium, but a small outcrop occurs at the junction of the Wátrak and Májham river 1¼ miles lower down. Two miles or so further down the Wátrak is a small outcrop of trap in the bed and right bank of the river, but below this every trace of it is hidden by the alluvium.

Relations of the trap and laterite at Paori Moti.

Unfortunately there is no section showing the relation between the trap series and the highly ferruginous laterite beds, which cross the river between Paori Moti and Thalpurá. On lithological grounds this laterite is assumed to be of the age of the laterite in the Surat and Broach country and the valley of the Tapti, which is unquestionably eocene, as it underlies limestones abounding in nummulites. Unfortunately, however, no fossils of any kind were found in these Wátrak valley laterites, nor in the very similar laterites of the Sábarmati valley; their age is therefore questionable; but if they are homotaxial with the southern beds, it is clear that the Deccan trap, if it ever extended over what is now the upper Sábarmati valley, had been completely denuded away before the deposition of the laterites, for they there rest directly on the surface of the archæan granite. The Paori Moti laterite may certainly be regarded as an extension of the laterite occurring to the east and west of Kapadwanj, and this deposit certainly appears to overlie the trap lying eastward of it.

B. In the Sauli Taluq :—

In Sauli taluq.

Coming southward into the Baroda Prant, trap rocks abound at the extreme N. end of the Sauli taluq. In the Kun river they are seen to rest upon the lower marine cretaceous Bágh beds described above (p. 48). The basement is a basaltic one in which much characteristic columnar clearage is seen, the columns are however exceedingly short, rarely attaining as much as a foot in length.

The greater part of the Ḍesar subdivision of the taluq is occupied by trap, mainly by basalt, which is best seen in several small hills rising from 30′ to 60′ above the plain to the N. W., N. and E. of Vejpur. The Battako dongri (1¾ miles E. of Vejpur) stands on the summit

of the watershed between the Mahi and the Mesri and is a somewhat prominent object in the landscape.

Trap rocks in the Mahi River.

A very fine show of trappean rocks is to be seen in the great reach, extending for miles nearly due E. to W., from the first bend below the railway bridge at Pali. The rocks are very rugged owing to the violent action of the river which flows with great impetuosity, and at half floods must form a series of great rapids. At low water there are abundant proofs of this in the form of great numbers of large pot holes and much water polishing. Numerous large pools full of rocky islands and small crags make the great reach very wildly picturesque at the beginning of the hot weather.

Tufaceous agglomerate.

The rock seen in the Mahi opposite to Jambugora, and further down the river consists of a very typical agglomerate with a matrix of grey black colour, which encloses fragments of traps of many varieties and colours: black, brownish, reddish, grey, greenish, &c. It includes also many characteristic bits of amygdaloid of very various kinds. The included fragments are all of moderate size, few attaining the dimensions of a man's head. No amygdaloid enclosures and no vesicular structure were observed in the matrix of the agglomerate which appears to be of great thickness. The relations of this great agglomerate, to the basaltic rocks southward of it, are hidden by the recent superficial deposits, but a somewhat similar agglomerate underlies a basaltic flow in the valley of the Mesri river to the south.

Lower down the Mahi at the Warsara ford the tufaceous agglomerate shows several intercalated basaltic and amygdaloid flows, which however are rather ill-defined, as if they had been poured out in such rapid succession, while the lower flows were still unconsolidated, that the contact surfaces had amalgamated.

The great show of trap rocks in the lower reaches of the Mahi and of its tributaries proves that in this quarter the old alluvia all rest on a trap surface.

The surface of the trap rocks south of the Karad river is however as a rule so completely obscured over the low downs, which form the eastern side of the taluq, by thick overlying black soil, that it is only by a few well sections

that the existence of trap is revealed. The downs are due to the local erosion of the westerly extension of the trap series. I have therefore shown them on the map and have ignored the overlying black soil despite its great extent and thickness. The boundary lines, however, could only be drawn in a manner loosely approximate to the truth and will be liable to some correction by future observers when, with advancing civilization, fresh sections are made revealing the true position of the sub-rock.

The sections revealing the underlying trap rocks in the south-eastern part of Sauli taluq are the following :—

a. A well section at Waria, exposing rather hard grey amygdaloid.

b. A well section at Aklia, a softer weathered amygdaloid.

c. Outcrops in the bed and banks of the Darakshi river are indurated semi-calcareous flaggy gritty ashbeds of grey colour with associated cherty partings.

At the junction of this stream with the nullah flowing southward from Rajpur, is a considerable show of a purplish small celled amygdaloid of but medium hardness, and half a mile further down the Darakshi stream are numerous small outcrops of a hard purplish tufa occurring at the ford W. of Boridra village.

C. In the Waghoria Taluq :—

Sections in and S. of the Vishvamitri river.

Several small outcrops of trap in the Vishvamitri river to the west of Asoj reveal its existence below the local alluvium. The rocks seen about the centre of the second reach, below the junction with the Dharakshi river, are indurated semi-calcareous ashbeds with associated cherty bands and siliceo-calcareous partings dividing it up into flaggy masses of considerable hardness. This flaggy bed is underlaid by a very soft purplish ashy bed whose base is not seen. The thickness of the flaggy bed is small, not more than 4 or 5 feet, and the beds roll about gently. They are exposed for about 200 yards. Further down the river soft tufaceous beds are very slightly exposed.

The existence of the trap series below the black soil covering of the low downs lying south of the Vishvamitri is

indicated by the sections afforded by two recently sunk wells, the one occuring at Abrampur and Amritpur, the former 2½ miles N. N. E., the latter 1¼ miles W. by N. of the N. end of the overflow channel of the Ajwa reservoir. Contrary to expectation, the cutting made for the overflow channel, does not penetrate the surface deposits which are locally very deep. At the former place the rock sunk into, was a soft ashy amygdaloid; at the latter, a moderately hard brown earthy trap, mottled with black.

Proceeding further south, along the eastern boundary of the taluq, traces of basalt are met with a little to the N. of Sangarol 3 miles N. E. by E. from Waghoria, but the rock is not seen *in situ*.

Trap in the Deo river bed.

Further south still a long narrow exposure of Deccan trap, a black vesicular basalt, is found in the bed and banks of the Deo (Dev) river, which outcrop commences at 2¼ miles S. E. from Waghoria and extends down the river till within a quarter of a mile north of Viara, a distance of nearly 2 miles.

Bairapur rise.

About two miles N. E. by E. of Viara, along the southern edge of the top of a low flat-backed rise, is an exposure of very black hard basalt (full of small crystals of olivine) immediately south of the little hamlet of Bairapur (not shown in the topo. sheet) which appears to be part of a flow occupying a considerably higher platform in the series, than the vesicular basalt seen in the Dev river. On all sides the extension of this trap is completely hidden by the overlying black soil which spreads over the surrounding alluvium as well. The matrix of this trap rock approaches a pitchstone in its semi-vitreous texture. No similar trap was met with elsewhere in the Gaekwari.

D. In the Sankheda Taluq :—

Very little Deccan trap has escaped the great denuding agencies which affected this part of Gujarat so remarkably, prior to the deposition of the old fluviatile alluvia. What remains is to be seen in ten patches, nine of which are quite small, the tenth only, the most southerly of all, being of any size. The first four are in the main division of the taluq, the remainder being in the outlying Amroli mahal.

In the Heran valley.

a. The first patch in the bed of the Heran, at Wasna, shows in the form of small hummocky masses 2'—3' high standing up among the coarse, river shingle. The area of this patch measures about 150 yards from N. S. and somewhat more from W. E. The rock is mostly a basalt passing here and there into a small celled amygdaloid.

b. The second is a tiny patch forming an outlier on the top of the Bagh beds crest of the watershed ridge 1 mile S. by E. of Sihadra; the third (*c*) lies south of the Rani Talao, a small roadside tank on the south side of the same ridge $1\frac{1}{4}$ miles S. of Nathpur.

In the Aswan valley.

c. The fourth (*d*) occurs $1\frac{1}{3}$ miles further W. S. W. between Sidhikua and Kaletia and also on the south slope of the standstone anticlinal. The trap rock seen in these two small patches is a highly decomposed crumbling substance apparently part of an ashbed. Very little of it is seen on the surface, but it peeps out in a number of small rain gullies which have cut through the overlying black soil. These patches are of no practical use and of no interest whatever, except as surviving fragments of the former extension of the Deccan trap flows over this region.

In the Men valley.

e. The most northerly of the outlying patches in the Amroli mahal occurs on the north side of the Nawágam tappa and is about 300 acres in extent.

f. A patch of basaltic trap of slightly smaller extent occupies the rising ground east and south of Nawágam and terminates southward in a low rocky ridge of weathered basalt along which runs the State boundary line.

g. and *h.* are two small trap inliers in the bed of the Men river, resting on Bagh sandstones.

i. is an outlier of weathered trap on the N. side of the Baroli ridge of Bagh sandstones at Khaparia.

j. is by far the largest patch of the Deccan trap series in the Sankheda taluq and is really an extension of the northern spurs of the Rajpipla hills. The trapflows in this patch are mainly basaltic. In the southern part they form steep hills, the highest, Jaski hill, being 681' above sea level and nearly 300 above the plain to the N.

A noteworthy fact, with regard to the trap rocks in the northern and central parts of the State, is the undisturbed

condition in which they have remained since they were poured out. With two small exceptions, one in the "*f*" and one in the "*j*" patch, no traces were seen of any dykes of younger trap intruded into them, and the comparative horizontality of the flows is quite undisturbed. In the southern division a great difference will be seen in this matter; the flows are cut up in every direction, with great dykes of various varieties of trap, which have tilted the flows considerably in parts, and being generally of much greater hardness and durability stand up in high ridges and to a great extent destroy the stratified appearance of the series of flows.

E. In the Velachha Taluq :—

The flows of the Deccan trap series occupy the eastern half of the taluq including the Wakal subdivision, and the hilly tract they form there must be regarded as a westerly extension of the Rajpipla hills.

The western side of this trap area is bounded, partly by the alluvium of the Kim river, and partly by the eocene (nummulitic) limestones, gravels and laterites of Naroli Nahani. The trap country rises slowly but steadily away from the western boundary, and at a distance varying from three to five miles becomes hilly, the hilly tract lying on the southern and eastern sides of the trap area. The higher hills rise from 250 to 400 feet, or more, above the country surrounding them and are mostly clad with small tree jungle. The summits and ridges of many of the hills are formed by dykes of harder trap, traversing the country in various directions, which have, by their superior hardness and durability, suffered much less from general atmospheric denudation than the softer flows they were intruded into.

The most north-westerly sections of the trap rocks in the eastern half of the taluq are to be seen in the Mangrol Kari[1] (the principal tributary of the Kim) and the Moti Kari, those in the latter stream being much the best exposed and most extensive. The beds seen are almost entirely soft reddish amygdaloids and ashy beds, both very greatly decomposed. They are traversed by numerous veins of hard brown or blackish impure calcite from a few

Calcite veins.

1 Kari is a Gujarati word meaning a small river.

lines to nearly a foot in thickness.[1] Many of these were noted traversing decomposed trap in the banks of the Mangrol Kari at Harsani. Above the trigonometrical station on the left bank of the Moti Kari and at Gad Kach hamlet a much harder, but still very decomposed basaltic trap, shows.

At Vasravi much basalt debris lies about on the surface and in the bed of the stream next to the great slag mounds, eastward of the village, a decomposed trap rock full of olivine crystals was noted.

F. In Kamrej Taluq :—

Very little trap rock of any kind is seen in this taluq owing to its being mainly covered by the great band of coastal and fluviatile alluvium extending far up the valley of the Tapti. In the north-western part of the taluq, the alluvium and overlying black cotton soil, cover up the sub-rocks up to an elevation of between 80 and 90 feet above sea-level. North of the contour line of that elevation the nummulitic series are exposed, but are not sufficiently eroded anywhere for the underlying trap to be revealed. It is only to the eastward of the lateritic ridge, in which the basement bed of the tertiary rocks is exposed, that the Deccan trap becomes visible, and here it is seen in form of a greenish brown crumbly decomposed mass. This exposure lies immediately E. of the 168′ trigonometrical station on the summit of the southern and highest extremity of the Naroli Nahani laterite ridge just referred to.

A small show of both basaltic and amygdaloid traps occurs ¾ of a mile S. S. E. in the bed of the Tapti on its southern side.

About 4 miles higher up the river bed a great show of trap, chiefly basaltic, forms the floor of the bed in the channels on either side of the islands lying N. of Nagod and Rudhwara for a distance of rather over 2 miles.

G. In Vyara Taluq :—

The Vyara taluq the whole country, excepting small tracts of alluvium in the valleys of the Tapti, Mindhola, Purna and

1 Some may possibly consist of pure and transparent calcite, as some fair pieces of such a variety were brought to me for inspection at Velachha, but the finder could not tell me the name nor the position of the place where he had got them; so I could not look up the locality.

Ambika rivers, consists of different flows of basalt, amygdaloid and porphyritic trap traversed in various directions by dykes of younger trap rock subsequently intruded. These younger intrusive rocks are in nearly every case much harder and denser in texture than the flows they have been intruded into, and have suffered far less from the eroding action of atmospheric agencies, and in consequence, stand up well above the general surface of the country, and form the sharp cut narrow ridges and crests which characterize that region. These are well shown on the 1 inch Topo. Map (sheet 34). The flows occupying this region are more disturbed than the members of the Deccan series generally are, for they certainly do not present the same level terraces that are seen in most parts of the Deccan where intrusive dykes are absent; such terraces for example as are typically seen on the Pavagad mountain 90 odd miles to the north. No deep sections were seen in the northern half of Vyara taluq, and the identification of any of the distant flows could only be effected by a much closer survey than I had the time to execute. Basaltic flows appear to predominate, but this may possibly be only an imaginary predominance due to their superior hardness having enabled them to resist to a greater extent the general levelling action of the atmospheric agencies, than the softer amygdaloid and earthy flows intercalated among them.

In the Tapti.

In the long reach of the Tapti, extending upwards (eastward) from the Gaekwari village of Kanja, the river has cut through an extensive amygdaloid flow and has got down on to a hard basaltic flow which at the lower or western end of the flow, forms a barrier across the river, causing a strong rapid which has cut deep channels through the hard rock. This barrier offers a very formidable obstacle to the navigation of the river and must be a great hindrance even to the mere rafting of timber down the river, for the barrier and the bad rocky bed below it, extend for all but two miles down the river.

Porphyritic Trap.

To the southward of the amygdaloid tract south of the Tapti much porphyritic basalt appears, the porphyritic structure being due to the presence of enclosed crystals of sanidin felspar which are scattered through the mass.

The crystals which are of a pale greenish white or drab are often twinned and mostly of small size, less than an inch in length. To the W. and S. W. of Vyara town the porphyritic trap is very largely developed and shows at frequent intervals above the surface soil.

In colour the porphyry is grey, freely, or sparingly speckled with the pale crystals as the case may be, and presents, especially where the crystals abound, a very handsome appearance. If susceptible of taking a good polish, it would be a very handsome stone for decorative purposes.

Dykes. The dykes of this region vary considerably in their petrological character, the leading types being dioritic, but andesitic and basaltic forms are also met with. Whether these varieties are restricted to dykes having special courses, was not ascertained, but it is very probable that such will prove to be the case when special attention is directed to the point.

This relationship between the direction of the dykes, and their mineral character, requires to be studied all over the Deccan trap area, and a special study of it should be made for the tracts north of the Tapti where dykes are developed on a very great scale.

The more important dykes show the following courses :-

N. 20° W.	N. 31° E.	E. 32° N.	N. 40° W.
N. 29° W.	N. 50° E.	E. 15° N.	N. 50° E.
N. 5° E.	E. 30° N.	N. — S.	E. 20° N.

H. In the Songad Taluq :—

The whole of the Songad taluq so far as examined, consists of trappean rocks belonging to the Deccan series. The alluvial and sub-aërial formations are of such trifling importance that they may well be passed over with but very brief reference.

The northern and southern parts of the taluq are essentially rugged and hilly.

The hilly tract north of the Tapti, as already pointed out, must be regarded as an extension of the Rajpipla range, while the hills south of the Songad valley, are as distinctly spurs of the great Sahyadri range.

The Nanchal hills dome. The most remarkable feature presented by these northern

hills, which I will call the Nanchal hills after the name of the subdivision of the Songad taluq they stand in, is a swelling up of the constituent trapflows into a low dome which attains its apex in the Toran hill trigonometrical station, a point 1,334′ above sea-level and 13 miles N.N.E. of Songad town. The southern and western sides of this dome have, as already mentioned, been much more deeply eroded than the northern or eastern sides, doubtless because much more exposed to the full violence of the S. W. monsoon winds and rains. The northern slope in particular is much less deeply eroded, but no special hardness of the rock is apparent to which the lesser degree of erosion could be ascribed.

The lines along which the denudation has been most effectual are largely due to the lie of the great trap dykes whose superior hardness told wonderfully in the formation of water partings. The principal lines of strike of the great dykes are the following:—

E. — W.	E. 7° N.	E. 26° N.	W. 26° N.
N. E. 5° N.	E. by N.	N. 23° W.	N. — S.
N. 20° E.	E. 35° N.	W. 10° N.	
E. 14° N.	E. 20° N.		

Songad Hill and Fort.

In the central part of the taluq the most remarkable feature is the Songad hill (see page 10), a very bold and striking eminence rising above the general level and forming an approximately perfect cone.

It owes its survival to the great sweep of denudatory action, which passed over the trappean series prior to the commencement of the tertiary (nummulitic) era, to the presence of two important dykes of hard trap which can now be seen on the north and south shoulders of the hill respectively. These hard rocks evidently acted as breakwaters which saved the intermediate softer flows, in great measure, from the eroding action of the sea which surrounded the highlands, formed by the immense pile of volcanic rocks, raised during the cretaceous period, for a long period and with great assistance no doubt from subaerial agencies carved it into an approximation to its present shape. How tremendous this eroding action was will be understood when the physiographical features of the country between the north-western end of the Sahyadri range and

the great outlying mass of Pavagad are studied. The accompanying diagrammatic section (Plate III.) will help to make this clear.

Owing to want of time the hilly tract in the south-eastern part of the taluq had to be left unsurveyed, but no doubt exists, that the whole tract is occupied by rocks of the Deccan Trap series and the map has been coloured accordingly. The two most noteworthy features of that large trap area, especially in the Dangs, are its extreme ruggedness and the very remarkable meridional disposition of the hills and valley which form great series of strictly parallel ridges and troughs with north and south axes.

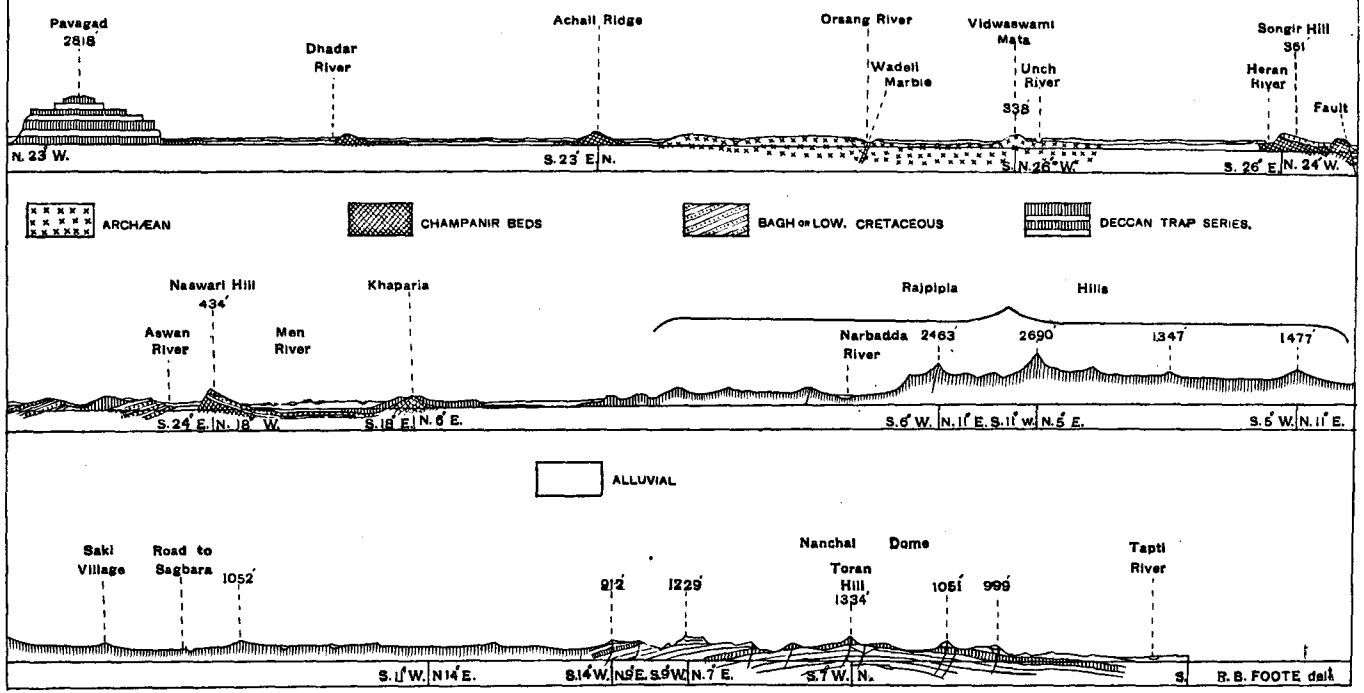
Formation of the western highlands.

That the shape of the highlands of India, from Malwa down to the southern end of the peninsula, was rough hewn into an approximation to their present outline by the action of the tertiary sea, will not be doubted by any observer competent to study the subject. The sequence of events which took place to bring about the mighty changes which led to the formation of the western highlands of the peninsula of India generally, and of Gujarat in particular, must have been approximately the following:—The enormous weight of the huge succession of volcanic rocks poured out subaerially over Western India during the cretaceous period, had caused the crust of the earth in this region to be depressed so greatly that this vast pile of volcanic rocks came to be exposed to the attacks of the sea along its western side, while the further outpouring of lava flows from the bowels of the earth having ceased, the surface of the country was equally exposed to the mighty agency of subaerial denudation which still continues at work energetically.

That the earth's crust is not absolutely rigid but sinks and rises accordingly as it has heavy weights imposed on it, or removed from it, is a fact now generally recognized. As in the process of time the action of the combined agencies removed a vast mass of the volcanic pile the lightened crust rose again, the previous balance having been in some measure restored. The relative amount of work effected by the two great agencies respectively is not easily comparable, for there is no evidence remaining

SECTION FROM PAVAGAD TO THE TAPTI RIVER ACROSS THE SANKHEDA TALUQ

Distance 92 Miles; Horizontal Scale 4 Miles = 1 Inch; Vertical Scale x 2 Nearly.



Reg: No. 4795
Photo-Print, Survey Office, Madras.
1899

to show what was the thickness of the uppermost and latest flows which have, in all probability, been entirely removed without leaving any trace of their existence. The amount of subaerial denudation was doubtless very vast, as the area over which it could operate was greatly more extensive than that over which the sea could operate; still, the effects produced by the latter are much more visible to the eye because of the production of great cliffy scarps and corresponding terraces such as are to be seen in perfection on the flanks of Pavagad hill, to name only one example, within the limits of Gujarat proper.

The formation of these noble lines of cliff and terrace was of course greatly furthered by the tabular disposition of the successive flows, and their accompanying agglomerates and ash beds. The existence of the softer formations over, and underlaid by harder and more resisting rocks, necessarily influenced the rate and direction of the advance of the surf action. Where the surf worked against a hard basaltic or dioritic bed the rate of progress was necessarily rather slow, but where a soft ashy bed was exposed at the surf level, the undermining action of the breakers must have proceeded quickly and made rapid inroads into the coast line and have given rise to frequent successions of fall of great masses of the superincumbent hard flows. The succession of many lines of cliff along what was the sea-face of the highlands proves conclusively that the secular rising of the earth's crust progressed at intervals, rather than continuously.

The enormous amount of waste undergone by the trap series is strikingly illustrated by the immense accumulation of agate pebbles in the conglomerates of the eocene (nummulitic) beds still remaining in the low country of Gujarat. The very small number of large geodes which, relatively to the thickness of the flow occurs in even the most richly geodiferous amygdaloid beds (a striking example of which is noted on the next page) proves what an immense thickness of such amygdaloids must have been worn away to furnish material sufficient to make up the vast gravel beds, consisting largely of geodes of great size, seen at the base of the eocene (nummulitic) system to the south

of the Narbadda near Ratanpur and between the Kim river and the Tapti at Naroli Nahani, and to the N. E. of Gallha (Golla of the 8 miles to the inch map).

I. In Moha (Mahuva) Taluq :—

Only a small part of the area of this taluq is occupied by trap and the only good sections of it are in the bed of the Purna above Moha town. In the river bed the different flows both amygdaloid, porphyritic, and basaltic, are seen dipping westward at low angles. Amygdaloid beds appear to predominate on the whole.

In the western part of the taluq, a very low basaltic plateau capped by a few small hills, also basaltic, forms a slight eminence above the surrounding alluvium.

The few small inliers of trap in the bed of the Wallan river, and the larger ones in the bed of the Ambika river, offer no sections of sufficient interest to merit separate description.

J. In the Palsana Taluq :—

Only one section, showing the trap rocks, is known within the limits of this taluq and this occurs some 8 miles E. by N. of Palsana town and extends for a distance of 4 miles in the deep bed of the Mindhola river. The only flow worth noticing here lies just about S. E. by S. of Nadira village. It is a pale greenish highly decomposed amygdaloid which contains here and there a few amygdaloids in the form of agate geodes of unusually large size and mostly of flattish shape. Individual geodes were noted from 6 to 8 and 10 inches across.

K. In Gandevi Taluq :—

A very small area of trap rocks, only about 3 square miles in extent, occurs in this the most southerly part of the Nausari Prant. The chief show is a small basaltic ridge, running for about a mile N. E. up to the hamlet of Wangri, 4 miles E. N. E. of Gandevi town. Wangri hill, which is nearly 200 feet high, shows well above the alluvial plain.

CHAPTER VII.

THE NUMMULITIC SERIES.

The recognized representatives of the great Eocene division of the Tertiary rocks in Gujarat all belong, as far as at present determinable, to the Nummulitic series lying mostly near to and in the valleys of the Tapti and Kim rivers, and forming the base of the system, but all the rocks in other parts of Gujarat that appear to be assignable to it, are unfortunately, quite unfossiliferous, so some doubt remains as to the absolute certainty of the reference of all those formations to the group in question.

Laterite formations.

The doubtful formations are a number of mostly richly ferruginous lateritic rocks, which crop up from under the alluvium in several parts of the country, beginning with the upper valley of the Sábarmati in the North, and the valley of the Wátrak in Dehgam Taluq and in the valleys of the Kim, the Mindhola and the Ambika rivers in the Nausari Prant. These rocks, though very carefully examined, proved in every case to be quite unfossiliferous and they would have had to remain unclassified had it not been for the fact that precisely similar rocks occur in the valleys of the Kim and Tapti closely associated with rocks abounding in Nummulites and other Eocene fossils.

The several formations above referred to, will be described in order of their occurrence, beginning with the outcrops in the bed and banks of the Sábarmati and proceeding southward.

In the Sábarmati valley at Virpur.

At the very spot where the Sábarmati first touches Baroda territory in North Lat. 72°50′, and 11 miles E. by S. of Vadnagar in the Kheralu taluq, lateritic rocks associated with grits and sandstones are seen resting on the granite and overlaid by the old alluvium of the river which in its turn, is capped by loess.

Jawanpura section.

The section is best seen in a rather deep gully which opens into the river from the west, and the northern side of which lies in Mahikanta territory belonging to the state

Ilol. The bed of the Sábarmati is here, in what I will call the Jawanpura reach, occupied by a wild chaos of granite rocks and blocks moved out of place by heavy floods. Great rocks, nearly all deeply weathered, form the lower part of the right bank of the river and on them rest the lateritic rocks,—which however are not well seen here, being thin and but ill exposed. Further south, the lateritic rocks, consisting of a laterite bed underlaid by a grit bed, are better seen, but seem to be thinning out and are only 2 or 3 feet each in thickness but in the opposite left bank of the river they form a cliff of some 20′ to 30′ in height. Half a mile further down the river the lateritic partings vary from a few inches to 4 or 5 feet in thickness. They are mostly rather harder than the sandstones and weather out into narrow ledges which from time to time break off as the underlying softer sandstones crumble away. Four lateritic partings may be distinguished on the left bank near Asoria, but on the opposite right bank, 3 at the utmost. The lateritic beds are by no means always continuous but are in parts represented by short lenticular masses. Locally much infiltration of ferruginous matter has extended downwards from the bases of the lateritic beds into the grey or drab or whitish sandstones below.

Hard grit bed at Virpur.

An exception to the rule of the sandstones being soft is to be seen on the top of the right bank east of Virpur, where a bed of hard reddish brown waxy grit overlies the rough grey gritty sandstone which there forms the base of the series and rests on the granite. Only a few hundred square yards of this hard grit remain visible at present, but it doubtless extends some distance westward under the alluvium.

South of the gorge formed by the Sábarmati, between Virpur and Eklara (on the right bank) the gritty beds form a steep cliff 30 to 40 feet high, in which a small cave occurs, formed by the action of a spring which has washed out the gritty sandstone. The cave measures about 120′ in depth by between 15′ & 20′ in height at its mouth;—it may have been enlarged by human agency, but is too damp ever to have been a regular dwelling place.

The Jer Waterfall.

Not quite a mile further south, where the laterite and grit have thinned out very greatly, a small stream has cut

a miniature cañon in the soft decomposed granite, into which at the time of my visit, a very good volume of water was falling and forming a very picturesque little cascade about 20′ high. The walls of the cañon were in parts profusely covered with a delicate maiden-hair fern.

Springs.

Very little water appears to reach the river by surface streams, except during the rains, nearly all the rain water which falls being swallowed up by the sandy loam surface, to be turned out in springs at the base of the river side cliffs, wherever an impervious stratum occur to check its further descent.

Laterite beds in the sandstone series.

Rather further down the river are several sandstone formations with thinner beds of laterite as partings. The sandstones are generally rather soft and mostly ill exposed, on the rather shelving right bank of the river, though well shown in the opposite or Mahikanta bank which is much more cliffy. Shades of white, pinks, purplish, lilac, lavender and red characterize the sandstones, the white predominating in the centre.

Phudera sandstones.

At Phudera, about 5 miles below the Virpur gorge, the sandstones are harder in texture and a very pale pinkish drab or brown bed, exposed in the dry bed of the river, was being quarried to some extent, at the time of my visit at the end of February. The bed shows a dip of 2° to 3° West. The few joints seen in the bed are mostly helpful to the quarry men. This bed and two other thinner ones resting on it, show ripple marked surfaces. The beds generally roll about at low angles—in all directions, for further up the river they show a very flat N. to S. anticlinal arch in the eastern cliff. A mile down the river from Phudera, a show of massive greyish gritty sandstone from 40′ to 50′ thick, is exposed at the mouth of a big gully which there opens in the right bank of the river (half way between Phudera and Pedhamli). This gritty bed which is exposed for several hundred yards up the gully had been deeply eroded by the stream flowing down the gully in the rainy season, and is for some distance cut into a miniature cañon with overhanging sides from 16 to 20 feet high with a nearly flat floor, a true bed surface. The cañon appears to have been eroded along a large joint fissure in the rather soft grit. Owing to a bed

The cañon section.

surface the tops of the cañon sides are almost as smooth and level as an artificial quay. This thick grit is seen on the opposite side of the Sábarmati, to belong to the Lateritic series.

Pedhamli cliff section.

A little less than a mile further down the stream, at Pedhamli, occurs what in point of colour, is much the most striking section of this series of rocks. A thickness of nearly 20′ of variegated, soft, clayey, thin bedded sandstones forms here a cliff of the brightest colours as pink, purplish, lilac, lavender, red and white; the last predominating in the central part of the section.

Underlying these gaily coloured beds lies a thickbedded grey, medium hard, sandstone, the base of which is hidden by the river. Owing to the position of the deep river channel close in to the foot of the cliff no good sketch of the cliff was feasible, which I much regret, as the section of the overlying alluvium and loess, was a very interesting one. The base of the alluvium, locally a strong grey sandy conglomerate, rests on the strongly eroded surface of the sandstones in very marked unconformity.

Owing to the rolling about of the beds of the lateritic series it is not exposed in many places, where it might be looked for, as the course of the Sábarmati is followed downwards, and for 4 miles below Pedhamli no show of it, worth mentioning, is met with, but then, at a point a mile S. E. of the large village of Aglod, and six miles N. E. of Vijapur the river suddenly contracts from nearly half a mile in width to 100 yards or less, and flows in a narrow gorge between two great quays of sandstone, capped with laterite, of which the western quay on the right, or Baroda, bank rises to a much higher level than that on the opposite bank. It was not possible to get round to the front of the cliff as deep water flowed close under it, so I could not satisfy myself as the relations of the two laterite quays, but I think it most probable the western quay is formed by a lateritic bed lying 50′ or 60′ higher up in the series than that forming the eastern quay which dips westward and shows only a low scarp. The gorge is rather more than ¼ mile in length.

The upper gorge.

The lower gorge.

Just a mile further S. E. still, the river is again contracted by the presence of two lateritic beds which are

disposed in position similar to those in the gorge just described. The gorge is not quite so narrow and looks more imposing as the cliffs on both sides are higher and on the right bank must be from 80 to 100 feet high. The beds are most likely the same as form the upper gorge. The upper laterite bed is underlaid by pale and variegated shaley sandstones. Below the lower gorge no more representatives, of the lateritic series are seen, on the Baroda side of the Sábarmati and on the Mahi Kanta side they are lost sight of within a mile.

The laterite beds are, as a rule, rather poor in iron, but signs of a former small smelting industry were noted in a few places on the top of the bank near Pedhamli and Phudera.

No fossils found.

Not the faintest traces of organic remains were seen though they were earnestly searched for.

Paori Moti Section.

Outside of the valley of the Sábarmati only one instance is known of lateritic rocks, of supposedly nummulitic age, occurring in the northern part of the Baroda territory, and this was met with in the valley of the Wátrak 6½ miles N. E. by N. of Átarsumba and 13 miles E. by S. of Dehgam. The river has here, just east of the hamlet of Paori Moti, cut across a thick set of lateritic beds and made a cliffy gorge about a quarter of a mile long on its eastern side. The beds cut across have a dip varying from S. S. W. to nearly due south, on its western bank, and the angle of the dip averages about 20°. The upper part of the section shows hard richly hæmatitic laterite, massive in parts and nowhere very cellular. This is underlaid by mottled purplish and reddish sand and clay, much impregnated with iron by filtration. The base of the section is much obscured by talus and recent alluvium. The depth of the little gorge, at its northern end, is probably about 70 feet and its sides are overlaid by loess, which is here thicker than usual, a blown hill having been really piled over the general loess surface so that the top of the river bank is here 132 feet above the ordinary water level. The laterite is a hæmatitic ore, rich in iron, and would probably yield 30 to 35% of iron on working.

Laterite at Thalpura.

A few laterite rocks show in the water above the gorge close to the hamlet of Thalpura and they may possibly re-

present a lower band of a less richly hæmatitic laterite. Here again no fossils could be traced though very carefully looked for.

No lateritic rocks of any sort were met with in the Baroda Prant, but they and their associates, which are here unmistakeably of nummulitic age, occur largely in the Velachha taluq between the Nerbudda and Tapti river valleys.

Laterite and nummulitic rocks in Velachha taluq.

A not inconsiderable tract of country, in the Velachha taluq, is occupied by rocks associated with the well known nummulitic limestones of Tarkeshwar. Unfortunately the rocks are much obscured by the overlying superficial deposits, particularly by continuous spreads of cotton soil and alluvium in the valley of the Kim river, which divides the area occupied by these eocene rocks roughly speaking, in half. In the northern half, along the watershed between the Kim valley and that of the Nerbudda, *e.g.*, around Boridra and Dinod, the rocks seen are chiefly reddish lateritic sands or gritty beds covered over with red soil. Locally, the sands or grits are seen to be consolidated into fairly hard rock which is in all probability the normal condition of the lateritic beds, the sandy superficies being the result of long continued weather action.

Other rocks.

Two or three cases occurs of rocks of other kinds showing up, as for example a hard shelly gritty nummulitic limestone to the south of Dinod and a strong flaggy brown

Hathuran sandstones.

sandstone, at Hathuran close to the 189th mile on the B. B. C. I. railway there is a small show of flaggy sandstone in the tank bottom W. by S. of the village. The sandstone which is a fine dense flagstone has a low dip to the N. N. W. but is speedily covered up on all sides by black soil. But very little of the flagstone remains visible, and either its original extent was very limited, or else much has been quarried away.

Kosamba gravels.

A low hillock of gravel about 12 or 15 feet above the surrounding plain occurs close to the State boundary 1¼ mile westward of the railway at Kosamba. It is doubtful whether this gravel is to be considered of nummulitic age or alluvial and the same thing may be said of a much larger gravel deposit between Kosamba and Mahuvej on the high ground east of the railway line. The elevated position

however of these gravels is opposed to the idea of their being of alluvial age.

Whether the lateritic rocks capping the high ground near Boridra, just named, represents the basement laterite of the nummulitic system to be described presently, or whether they should be regarded as a younger formation, occupying a higher platform in the system, could not be decided from the sections exposed within the Velachha taluq, and there was no time to examine any part of the adjoining country, belonging either to the Broach collectorate or to the Rewakantha Political Agency, but Messrs. Blanford and Wynne regard them as equivalents of the lower beds south of the Kim.

Inliers in the Kim valley.

In the middle of the alluvial valley of the Kim, in the bed of the river, are several interesting outcrops of other rocks, clayey, calcareous sandstones or sandy clays, strongly resembling in appearance some of the European cement-stones. Considerable exposures of these are to be seen in the Kim in several of the small reaches S. E. and S. W. of Velachha itself. In colour these beds are mostly pale yellowish buff, but here and there they contain so much limonite as to be of a rusty brown and to become, locally, a true laterite. The mass of the rock is frequently very much permeated by small veins of calcite and nodular masses of darker sandy clay (some of them possibly rolled pebbles of an older clay) occur in great numbers, with here and there, a few agates converting the rock locally into a conglomerate.

The quantity of calcite veins, in many parts, is so great that it suggests the possibility of the rock being used on a large scale as a "cement stone" for the production of hydraulic lime. No fossils could be found in these beds despite very close search for them.

River sections S. W. of Velachha.

In the sections S. W. of Velachha this conglomeratic formation is overlaid by a homogeneous bed of the same texture and colour, in a nearly horizonal position.

Nummulitic limestone at Chhamusal.

These beds are on the south bank of the river covered by thick cotton soil which spreads over everything. Only on the top of the watershed between the Kim and the Tapti near Chhamusal are faint traces of nummulitic limestone exposed; this is an unquestionable extension of the

Tarkeshwar beds which occur in force a little further to the S.E.[1]. These rocks were visited and described by Messrs. Blanford and Wynne (see page 204 l. c.).

To return to the bed of the Kim river. A few small outcrops of buffy clayey sandstones are met with in the bed of the river about 2 miles above the great show in the Shettri reach before referred to (p. 71), but above these nothing is seen for several miles, everything being hidden by the overlying cotton soil and river alluvium. In the Vasravi nullah, a tributary of the Kim, a tiny exposure of buffy sandstone was noticed, just south of Charetha and

Laterite N. and E. of Mangrol.

in the Mangrol Khari, an affluent of the Kim, of equal size and apparent importance is a considerable section of lateritic rocks in the reach north of Mangrol village. In the cliff (30′—35′ in height) at Wadhri in a section 2—300 yards long is a bed of pipy brown laterite resting on red gravelly laterite, the base of which latter is obscured by four or five feet of talus. A $\frac{1}{4}$ mile N. of Mangrol a bed of softish conglomerate forms a low narrow barrier across the river bed. It contains many small agates and much nodular hæmatitic clayey iron stone. A mile and a half E. by N. of Mangrol is the last outcrop to be noted in the Khari river. The rock here seen is a conglomerate, a typical pudding stone, composed of rounded laterite pellets cemented together by a whitish calcareous matrix. This conglomerate must rest upon the Deccan trap series which shows up largely some 300 yards to the eastward just above the village of Harsani.

The basement laterite bed.

Immediately S. E. of the village of Naroli Nahani rises a low ridge consisting of reddish laterite, the basement bed as far as seen of the eocene rocks of this region. The ridge formed by this laterite outcrop extends S. S. W. with a few breaks all the way down to within a quarter of a mile of the Tapti, when it is covered by the river alluvium. The ridge is not perfectly continuous, but sinks down in several places in the central part of its course, almost to the general level of the country. It is most conspicuous at its northern and southernmost ends which are in Baroda territory

1. The Tarkeshwar Nummulitic rocks were discovered in 1861 by Mr. Alex. Rogers of the Bombay Civil Service, but his description of them does not mention their extension into Baroda territory, so his paper has not been referred to in the list of previous observers.

in the Velachha and Kamrej taluqs, respectively, the low central part lying in an intermediate protrusion of British territory belonging to the Mandwi taluq of Surat collectorate. This protrusion includes the nummulitic limestone tract of Tarkeshwar. Only two or three outcrops *in situ* of this limestone were seen in the southern part of Velachha taluq owing to the thickness of the almost unbroken spread of black soil which covers the watershed between the Kim and Tapti. The gneiss and granite country underlying the laterite ridge to the eastward is also very greatly obscured by the black soil.

In its southern part the laterite bed rests on the Deccan Trap, but I had not the time to spare to map the relations of the trap and granite areas outside the Baroda territory, in the valley of the little Rhea river.

To turn to the N. again, laterite is seen in at Surali in the bed of the Wasthan nullah, a small stream joining the Kim 2 miles E. of Velachha. It is also exposed at various places higher up the same nullah, close up, in fact, to the edge of the Deccan trap at Wasthán and westward, also down the nullah to the N. and S. of Nogama. On the rising ground S. of Nogama a great deal of nummulitic limestone débris is scattered about, though none could be found *in situ*. In colour it is buffy, weathering reddish, and abounding in fossils chiefly foraminifera of several species, *e.g.*, Orbitoides, ephippium, &c. No trace of this limestone was seen in the bed of the nullah which runs N. from Naroli Nahani, only a few blocks of gritty sandstone doubtfully *in situ* about 1¼ mile below the village. Limestone near Nogama.

The roughly triangular piece of ground lying between the northern end of the laterite ridge at Naroli Nahani and the eastern boundary of the Tarkeshwar township appears, as far as can be judged, despite the thick and mostly unbroken covering of black soil, to be occupied by a gravel formation, consisting mainly of agate pebbles, many of them of large size and great beauty. A considerable number of bloodstone (heliotrope) pebbles and some few agate jaspers were collected, and the deposit is one deserving of the attention of Government. This gravel occupies an identical position relatively to the laterite The Agate gravels.

basement bed as do the gravels in the northern part of Kamrej taluq 3 or 4 miles to the S. S. W., which will be described further on.

Limestone S. W. of Naroli Nahani.

At the south-western end of the northern section of the laterite are a few small outcrops of a shelly grey limestone exposed for only a few square yards. The included shells are species of ostrea, &c., but no nummulites or other foraminifera were noticed among them. The relation of this limestone to the gravel formation can merely be inferred, for black soil covers the surface too much to see any contact, but it will, I think, be found that the limestone lies directly on the laterite basement bed and is overlaid by the gravels.

The Nummulitic limestone.

Along the political boundary between Naroli Nahani and Tarkeshwar, traces of the nummulitic limestone commence to show in the shape of fossils, chiefly large foraminifera of the genus Nummulites which have been weathered out of the matrix and are scattered in numbers increasing rapidly to the westward. In many specimens the delicate "engine turned" pattern is very perfectly preserved.

Its extension northward.

There is every reason to believe that the fine buffy Tarkeshwar limestone extends northward under the great cotton soil spread, and it would be a wise measure to make a number of excavations to ascertain this fact, for the limestone affords a very fine and handsome building stone which could be quarried to great advantage for use in the many well-to-do villages in the valley of the Kim.

Eocene Rocks in Kamrej Taluq.

Limestone outcrops.

The great cotton soil spread, so often referred to above, hides the southern extension of the Tarkeshwar beds almost completely. Only three exposures of limestone were met with on the slope which descends from the Tarkeshwar watershed southward to the bed of the Tapti. These are respectively met with (*a*) to the south of Lindiad; (*b*) to the south of Limodra, nearly 2 miles further E.; and (*c*) four miles S. E. by E. of (*b*), and 2½ miles N. E. of Ghalha on the Tapti. At (*a*) a band of nodular yellow limestones shows along the cart track south of the village of Lindiad for about ¼ mile. No fossils were found in this locality. At (*b*) about ¼ mile S. S. E. of Limodra is a small outcrop

of very sandy drab limestone—a calcareous sandstone in part, jointed into small angular lumps. The whole is very badly seen and no fossils could be found in it. At (*c*) in a rain gully a few score yards south of the Nathu Pir tank a nodular brown and yellow brown limestone, full of large nummulites, is exposed by the weathering of the rock.

Agate gravel.

South-eastward of this limestone is a gravel formation, consisting largely of agates with some bloodstone and agate jasper pebbles. Many of these are handsome stones both in size and colour and deserving of the attention of the Cambay lapidaries. This bed, which extends westward for about a mile, is very ill-exposed.

Younger laterite.

The high ground, lying to the north of the Nathu Pir's tank, is largely covered with laterite and resulting red soil,—this laterite being a younger formation than that forming the basement bed and ridge.

Basement laterite.

The basement laterite ridge forms a well-defined ridge and near its southern extremity attains its greatest height of 168′ above sea-level and about 70 above the right bank of the Tapti, which flows half a mile to the southward. The laterite here is mostly pisolitic in structure and limonitic in composition, but here and there hæmatitic laterite, in patches of rich red colour, is met with. Its thickness is apparently considerable, but no section was seen in any part of it which allowed of measurement or even of close estimate of the thickness.

As before remarked, these eocene beds are very badly seen, owing to the great covering of black soil which overlies them and extends all over the southern slope and is rarely cut through by the local streams.

Section N. and N.E. of Karjan.

Beside the outcrops above referred to, only two others were noted, the first of which lies 1¼ miles N. of Karjan, where the road to Simodra crosses the large nullah flowing from the N. E. Here the nullah has cut a cliff 8′—10′ high of shaley drab clay overlaid by about 4′ of soft dirty reddish brown conglomerate, including pebbles of shaley clay and rather soft laterite; no fossils were found here, and but that similar formations are found further to the east in the bed of the Tapti, I should regard this clay and conglomerate as of

alluvial origin. The second exposure on the slope is a "naples yellow" coloured clay seen about ¼ mile N. E. of Karjan along the road to Virpur. No fossils were found in this clay.

A band of alluvium from 1¼ to ¼ miles in width divides the foot of the slopes from the bed of the Tapti, and the nummulitic rocks exposed in it, and no correlation of these latter beds with those above described is practicable at present.

Outcrops in the Tapti.

The outcrops in the bed of the Tapti are deserving of closer attention than those above referred to, as they do in some measure deserve the appellation of sections and several of them contain fossils of determinable character. Five of the outcrops require to be noticed, and they are the following, taking them in order from east to west :—

Section at the mouth of the Rhén.

a. The first of the sections is situated at the junction of the little river Rhén with the Tapti 1½ miles above Ghalha and can only be properly seen when the Tapti is at its lowest, as the base of the section is in the bed of the river. The lowest rock seen is a typical laterite lying at and partly within the mouth of the little Rhén river which here falls into the Tapti from the N. E. This laterite, which appears to be the southerly continuation of the "basement ridge," dips at a low angle estimated from 12°—15° W. S. W.

The surface of the section at the time of my very short visit to it had been much disturbed and obscured in its upper part by small landslips and by the digging of some people for a reddish clay which occurs in nests under the upper laterite. The diggers had thrown much débris over the bank shortly before my visit, and it was impossible to distinguish the different smaller beds named and measured in Messrs. Blanford and Wynne's detailed section given in the memoir on the Geology of the Tapti and Lower Nerbudda valleys, already several times quoted.

As the section is one of very great interest, I cannot do better than quote their description of it in full. The section is given in descending order :—

	FT.	IN.
1. Laterite about	10	0

		FT.	IN.
2.	Yellow sandy calcareous rock abounding in *Foraminifera* especially *Orbitolites mantelli*, D'ort. and *Orbitoides Ephippium*, Sow.	1	0
3.	Ditto softer	2	0
4.	Do. same as 2	0	6
5.	Do. softer and more sandy ...	2	0
6.	Do. containing beside the *Foraminifera*, *Vulsella legumen* and species of Bryozoa	6	0
7.	Similar rock but more calcareous; *Foraminifera* the same, but less abundant...	0	6
8.	The fossiliferous yellow ferruginous sand containing grains of brown hæmatitic.	1	6
9.	Sandrock also abounding in grains of brown hæmatite more compact than the last, containing *Gasteropoda*, *Corals* and a few *Foraminifera*	0	6
10.	Ferruginous sand with but few fossils ...	1	9
11.	Sandy bed rather less ferruginous, but still containing grains of brown hæmatite. In this bed occur bones apparently of mammalia, numerous *gasteropoda* pectens, oysters and other lamellibranchiata, corals and *Nummulites* obtusus, Sow. (or some species of similar form), but few other *Foraminifera* ...	8	0
12.	Laterite (base not seen) about ...	10	0

"The fossiliferous band is about 24 feet thick and may be considered as a whole."

"The following fossils have been identified by Dr. Stoliczka from amongst those collected:—

"Rostellaria Prestwichi, D'orb.
"Terebellum sp.
"Cerithium sp.
"Cypræa (cypræovula) elegans, Lam.
"Natica longispira, Leymerie.
"Conus sp., near C. brevis, Sow. but thinner.
"Trochus sp. (like T. Mitratus Dest.)
"Pholas sp.
"Pecten Hopkinsi, D'arch & Haime.
"P. Favrei, D'arch.
"P. corneus, Sow.
"Vulsella legumen, D'arch & Haime.

" Ostrea Flemingi, D'arch.
" O. lingura, Sow.
" Hornera sp. (near H. verrucosa, M.E.)
" Echinanthus, fragments.
" Cidaris spines and fragments of other echimada.
" Stylocani Vicaryi, M. Ed. & Haime.
" Trochoseris ?
" Trochocyathus, Vandenbeck in M. Ed. & Haime.
" Nummulites, perforata D'Orb.
" N. Brogniarti, D'arch.
" N. exponens or N. spira (probably both).*

The thick alluvium which overlaps the trap and the base of the eocene rocks at the south end of the basement ridge (the Nerolee Moonjlao bed of Mr. Blanford's memoir) hides, in all probability, one or more faults, to which the nummulitics in the above section appear to owe their present position which appears to be underlying the Deccan Trap seen on the west side of the 168′ Trig. station.

Rather more than a mile N. N. E. of the Trig. station the ridge is traversed by a fault to the N. of which the laterite bed is thrown about 300 yards to the W.

Dhantwa section.

b. Proceeding down the bed of the Tapti westward, for a distance of ¾ mile, the first outcrop met with lies on the left (or South) bank at and above the village of Dhantwa and opposite to Ghalha (Gulla). The beds exposed here in the bed and bank of the river are sandy conglomerates containing many small and a few large agates, also occasional pebbles of trap and of a yellow calcareous sandstone. The conglomerates themselves are yellowish buffy in colour and seemingly soft in texture, but really very hard at a depth of a few inches. They dip westerly at low angles, rarely exceedingly 5°. The only fossils found in them by me were a considerable number of fragments large and small of fossil dicotyledonous wood, with the annual rings of growth very obscurely developed, so much so that at first sight they were mistaken for fragments of coarse bone without any

Fossil wood.

* "In this list Orbitolites Mantelli does not occur, nor orbitoides ephippium. The latter certainly abounded in the upper part of the red, and so I think did the shell to which the former name is applied by Dr. Carter. The specimens had probably been mislaid." Among the fossils that I collected here were numerous examples of orbitoides ephippium in excellent preservation. The fossils I procured were left at Baroda waiting to be identified when books bearing on the subject could be procured.

articular surfaces. I chiselled out several with difficulty and then discovered their vegetable character. The largest seen was about 4 feet long and from 6 to 8 inches thick. The logs appeared to have been a good deal rolled before being embedded. The bed they are imbedded in, a nearly horizontal one, is a little above the centre of the section. These conglomerates resemble somewhat similar conglomerate at Karjan 1½ miles further W. N. W., to be referred to presently. Speaking of these Dhantwa beds, Dr. Blanford says: "They have evidently the character of the upper beds in the Keem and Oomrawuttee rivers."

c. A quarter of a mile W. of the Dhantwa section is another exposure of similar conglomerates also in the left bank of the river but requiring special notice from the fact that they show very great disturbance, for instead of dipping westward at a low angle they dip at the eastern end of the section south at an angle of 55° in "a well-marked measurable dip" and further west become absolutely vertical! No fossils were seen here, possibly because the surface of the conglomerate was much hidden by a muddy deposit left by the last flood that had gone down the river. Dungra section.

This very remarkable disturbance of these conglomerates must be connected with a nearly equally great disturbance of some conglomerate beds to be seen on the opposite bank of the Tapti in the lower half of the section at Karjan which must now be described.

d. In the right bank of the Tapti fronting the village of Karjan occurs a section fully a mile in length which may be considered as forming two minor sections, the one above, the other below the village. Of these the upper shows a set of conglomerates and sandstones in the following descending order in nearly horizontal position or dipping very gently to W. by N.:— Karjan section.

5. Soft sandstones.
4. Clay.
3. Conglomerate with sandstone nodules and fossils.
2. Sandstones soft with greatly developed diagonal bedding.
1. Conglomerate with sandstone nodules.

The bank is very broken, but the thickness of the beds exposed may be from 20 to 25 feet.

Sandstone N. 2. is locally utterly unconformable to the overlying conglomerate No. 3.

The fossils obtained from No. 3 were the following:—

Bryozoa, 2 sp.
Corals, 3 sp.
Pecten, 2 sp.
Ostrea, 2 sp.
Cidaris, spines of, rare.
Shark's teeth, 3 or 4 sp.
Palatal teeth, 1 sp.
Saurian teeth, 1 sp.

West of the village the conglomerate instead of resting nearly horizontally is, for a distance of several hundred yards, upraised to an angle of fully 50° N., but this dip is not shared by the upper beds of the series which looks as if a line of fault ran along parallel with the bank—and parallel also with an anticlinal arch which occupied what is now the bed of the river and has its opposite slope exposed in the upraised conglomerates at Dongar.—The arch of the anticlinal has been denuded away, but the sides of it remain still.

In a large block of this uptilted conglomerate just south of the path coming down to the water from the centre of the village numerous small shark's teeth were found beautifully fossilized and a slab (18″ × 14″) containing a very considerable number of them was successfully detached. The conglomerates of Karjan include very few agates, and those but small, but contain large number of large and small waterworn blocks of fine mudstone of yellow buffy colour (rarely grey). The surfaces of these mudstone blocks had been extensively bored by Pholadidæ, but in no case had their shells been preserved.

The Párdi-Dholan section.

e. The fifth and last section in the Tapti series occurs rather more than a mile below the Karjan section and on the same (N.) side of the river. The rocks exposed here are a great bed of sandy white or creamy clay underlaid by false-bedded sandstones interbedded with whitish sandy clays and shales and these underlaid in their turn by a strong rather iron-stained conglomerate containing many large pebbles of agate and older rocks (traps and crystallines) as well as many rolled blocks and pebbles of sandstone such as those described in the Karjan section. At a point half a mile above Dholan these rocks show a section fully 40′ in thickness in the cliffy river bank.

In the conglomerate are bands of shelly calcareous sandstone consisting in many places entirely, or very nearly so, of fragments of broken balani. Only a few small gastero-poda and two or three sharks teeth of the genus Lamna occurred with them.

Throughout the greater part of the section the beds are nearly horizontal, or show only a trifling dip to the W. or W.N.W., but close to the eastern end the conglomerate has been greatly disturbed and has a dip of 55° N. This inevitably suggests an extension westward of the disturbance seen in the western half of the Karjan section.

Below the Párdi-Dholan section no further outcrops of the Eocene series are to be seen in the bed of the Tapti, and the only remaining sign of them in the Kamrej taluq is the small laterite hill at Dungar 10 miles S. E. of Kamrej and 6½ miles S. E. by S. of the Rhén river section. This hill, which is a quarter of a mile long, rises about 100 feet above the great alluvial flat south of the Tapti. The surface has been much dug into for the stone which is an ordinary laterite. Whether the whole mass of the hill consists of laterite or not there was no means of judging in the absence of sufficiently deep sections. No other outcrop of laterite is known in Kamrej taluq. (See p. 9.)

Dungar laterite hill.

Only one solitary exposure of supposedly Eocene rocks is known in the Palsana taluq, and this is a deposit of typical hæmatitic lateritic gravel occurring on the top of the right bank of the Mindhola river two miles S. E. of Wanesa (5 miles E. by N. of Palsana town). Its extension westward under the general covering of cotton soil is unknown. Traces of an old iron industry remain in the form of slag heaps of small extent on the top of the river bank.

In Palsana taluq.

Two small exposures of laterite only were met with in Mahuva (Moha) taluq at the village of Kurel at the extreme western end of the taluq; of the two the smaller is a small bed of ordinary rock laterite which crosses the bed of the Purna ½ mile N. E. of the village and forms a little reef a score of yards or so in width which strikes from N. W. to S. E. with a low north-easterly dip. The second outcrop of the laterite occurs a quarter of a mile higher up the river on the left bank of which it forms the

In Moha taluq.

upper half in a steep cliffy section and rests upon highly decomposed greenish trap rock and is covered to the W. by thick cotton soil. The laterite in this section is not quite a typical one. Instead of the ordinary, rather vesicular mottled rock forming a continuous bed it consists of an agglomeration of hard tough masses 3′ to 4′ in diameter of a hæmatitic sandy clay of dull red colour surrounded by smaller gravelly nodules of the same texture. No included pebbles of older rock were seen in the bed which is from 20′ to 30′ thick (estimated). The westward and southward extensions of this laterite are completely masked by the overlying cotton soil, but enough of it is exposed to show that it may become a very valuable source of excellent road metal and good building stone in a country where stone of any useful kind is very rarely to be found. (See Chapter IX.) The relation of this high lying bed of laterite to the lower lying band crossing the Purna lower down is not determinable, no connection existing between them, but there can be little doubt that they were formerly connected in some way or other with the far larger and more important laterite formation which is exposed in and indeed constitutes the red hill at Tarbhan in the Baroli taluq of Surat district rather more than a mile to the N.E. Whether any further outcrop of laterite appears rising over the great alluvial flat lying between the Purna and the Ambika rivers is not known, certainly none was seen by me in the two traverses I made across the northern part of this flat; but to the south of the latter river further examples of this remarkable ferruginous clay rock are met with and deserve attention.

Kurel high level bed.

Laterite in Gandevi taluq.

10½ miles S. S. W. of the Kurel inliers and 2 miles N. of Gandevi town occur the first two of four inliers of laterite that might be made of great service to the surrounding country at sources of excellent metal where roads are practically unknown but very greatly needed.

a. The most northerly of the three inliers commences a little more than a mile south of the left bank of the Ambika river where it forms the northern boundary of the taluq and forms a low flat-backed ridge, ¾ of a mile long and about 300 yards wide, running from N. N. E. to S. S. W. —much obscured by cotton soil and grass at its northern

end. It is best seen at its southern end where the surface is cultivated. It rises 50 or 60 feet above the river flat and 88′ above sea-level at its highest point. The laterite is of a poorly ferruginous variety and occurs, as seen on the surface, in the form of a coarse nodular gravel.

b. Separated from the foregoing by a well-marked alluvial valley is a rather lower ridge running E. by N. to W. by S. for half a mile and thickly overgrown with trees. The rock, which is mostly of a gravelly variety and rather more ferruginous than the northern inlier, is best seen along the road from Gandevi to Khakhwara, and at the western extremity of the ridge in the bank and bed of the river. The rock here seen is a bedded, mottled pale red and white, hard sandy clay with a good deal of tubulated structure, and has a north-westerly strike with a high south-westerly dip.

c. Half a mile east of the town of Gandevi rises a low ridge rather more than half a mile long and some 50 feet high above the general level of the country, formed of blocky hard laterite, only moderately ferruginous in quality, which has been extensively quarried along the western end and southern side of the hill. The eastern end of the hill sinks down somewhat and is then lost in an easterly rising ground covered with thick cotton soil which hides the contact of the laterite with the underlying trap rocks further east.

d. In the reach of the Vegni Khari (river) 300 yards S. of the west end of the hill is an exposure of gravelly laterite resting on, or rather passing down into, a mottled pinkish and lilac lithomargic clay. As on the hill the laterite is poor in iron and consequently of a dull reddish colour.

In none of these laterites or the underlying lithomarges south of the Tapti were the faintest traces of organic life found; but from their position skirting the extremities of the spurs of the trap formation it is impossible not to regard them as representatives of the basement bed of the Naroli Nahani laterite ridge, and thus as indications of the extension into this region of the nummulitic series of which doubtless great part is now hidden under the fluviomarine coastal alluvium.

CHAPTER VIII.

THE ALLUVIAL AND SUBAERIAL FORMATIONS.

As before mentioned, the alluvial and subaerial formations cover by far the larger part of the State and are of the highest importance agriculturally but of very minor value minerally. They occupy chiefly the western, or coastal side of the country.

The purely alluvial formations can only be studied in the natural sections made by the various rivers and streams which drain the country. No artificial sections of sufficient depth to throw any light on their nature were met with during the progress of the survey, and their surface is almost universally covered by subaerial deposits in the form of either black soil (cotton soil or regur) or else pale blown loam (loess) and sand. These constitute the surface deposits of the whole country.

To the south-west of Baroda the loam skirts the line of railway for some miles, and then trends away still further south-west. The alluvium in the Nausari Prant appears to be everywhere covered by black soil, excepting over a small tract at, and to the eastward of Kamrej, while to the north of that place are also two small dunes of dark sand raised by the westerly winds blowing up the valley of the Tapti river whose dry bed consists largely of loose dark-coloured sand chiefly composed of weathered trap. Similar dark sand occurs largely along the seabeach south of the Tapti and Mindhola estuaries.

A limited narrow tract along the coast near Umrat is also occupied by sandy hillocks and small dunes raised by the west wind blowing over the beach. The sand in this case is lighter coloured than much of the beach generally, probably because of the wind not raising so many the dark trap particles whose specific gravity is higher than that of the pale quartz sand.

The ordinary black soil differs to the eye in no way from the typical black soil—Regur, or cotton soil, occurring so largely in many parts of Central and Southern India,

and nowhere were sections met with supporting the old-fashioned idea that the black soil was formed by the decomposition of dark trappean rocks.

Here and there, but only very rarely were indications noted of the formation of black soil deposits at periods anterior to that in which the general black soil stratum was accumulated. These earlier black soil deposits occur in the upper part of the alluvia of some of the principal rivers. The best example of this was observed in the high alluvial cliff on the right bank of the Heran river S. W. of Garda. Here a bed of black soil was noted at about $\frac{3}{4}$ of the height of the present vertical cliff. It was quite inaccessible for measurement, but I estimated it at from 3′ to 4′ in thickness and it is perfectly level in its position. An equal thickness of overlying pale loam separates it from the upper black soil formation, which is only 2 or 3 feet thick, which is probably a fair average of its thickness locally. Older regur deposits.

A remarkable phenomenon connected with the black soil was observed a little distance from the extreme eastern corner of the Gaekwari on the path leading from Wasna to Bagliwao. Here in a slight hollow near a small branch of the Kurwa Naddi were three circular half bare patches 3 to 4 feet in diameter which were the dry surfaces of cylindrical quagmires 8 or 9 feet deep. My guide got quite excited because I nearly walked on to one in my ignorance of its real character and told me I should have been swallowed up and smothered if I had actually stopped on to treacherous surface. Men and cattle are occasionally lost in these quagmires. I sounded one with a stick and it went down several feet into soft black mud. Despite the dangerous character of these well-like quagmires, the footpath I was following ran close between two of them without any attempt at a fencing to warn unwary travellers of their danger. I never saw such quagmires in other black soil districts, but heard of some on a rather larger scale in the great black soil tract occupying the central part of South Arcot. Well-like quagmires.

These well-like quagmires owe their origin to the presence in the subsoil of small springs which are not copious enough to rise to the surface in dry weather.

A. THE RIVER AND COAST ALLUVIA.

The alluvial deposits proved themselves strangely barren also of vertebrate organic remains. The only fossils obtained were a few bones I procured from a sandy bed at the top of the alluvium of the Orsang river, half a mile or so N. N. E. of Bahadarpur railway station. The bones I found there were all mammalian and mostly ruminant, but they have not been determined specifically. They are now in the Baroda Museum.

Beside these I was shown an elephant's molar, said to have been discovered at Sankheda on the opposite (east) side of the river. It had been made an object of worship (!) and had been so thickly covered with redlead and sacrificial oil that I could not make out whether it belonged to the existing Elephas Indicus or to one of the extinct species, and I could not obtain possession of it to bring it away for comparison with determined specimens in the Indian Museum or other collections.

Human remains.

Of human remains, the only traces discovered by me in the alluvial deposits, were four palæolithic implements and a worked flake, all of quartzite. These were procured from a shingle formation, low down in the alluvium of the Sábarmati river, occurring at two different localities both on the right bank of the river.

Palæolithic implements.

Palæolithic implements in Sadolia section.

The first of these localities was on the bank of the river 8½ miles S.S.E. of Vijapur and 3 miles W. 5° N. of Parantij, a town of some importance in the northern part of the Ahmedabad collectorate.

The first implement here found was a well-shaped worked flake, of purple quartzite, lying on the surface of a shingle bed, an imperfectly consolidated conglomerate, out of which it had evidently been weathered. My attention being thus roused, I made a close search as I went along, and a couple of hundred yards further south, came upon a very fine implement of the broad axe or Madras type. This lay close to the edge of the water; but from the shape of the little gully in which it occurred, it was absolutely certain that it could only have been washed down a few yards distance out of the same shingle bed as had yielded the worked flake found just before. I was unable to devote sufficient time that morning to make a really close examination of the alluvial section, so I re-visited the place the next day,

SECTION ACROSS THE SABARMATI RIVER WEST OF SADOLIA LAT. 23° 34' N.

Length of Section about one Mile.

W. by S. E. by N.

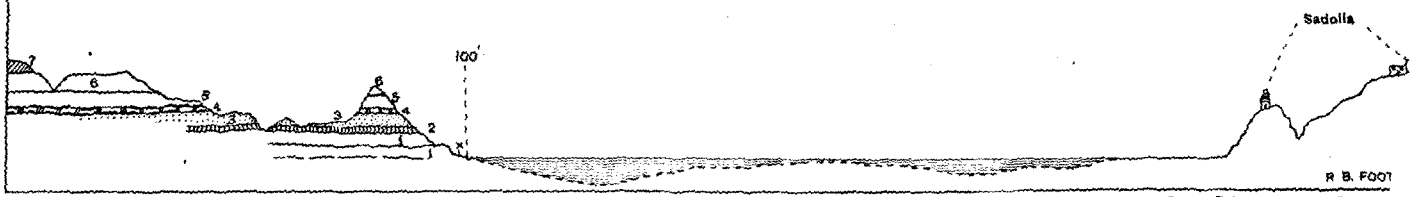


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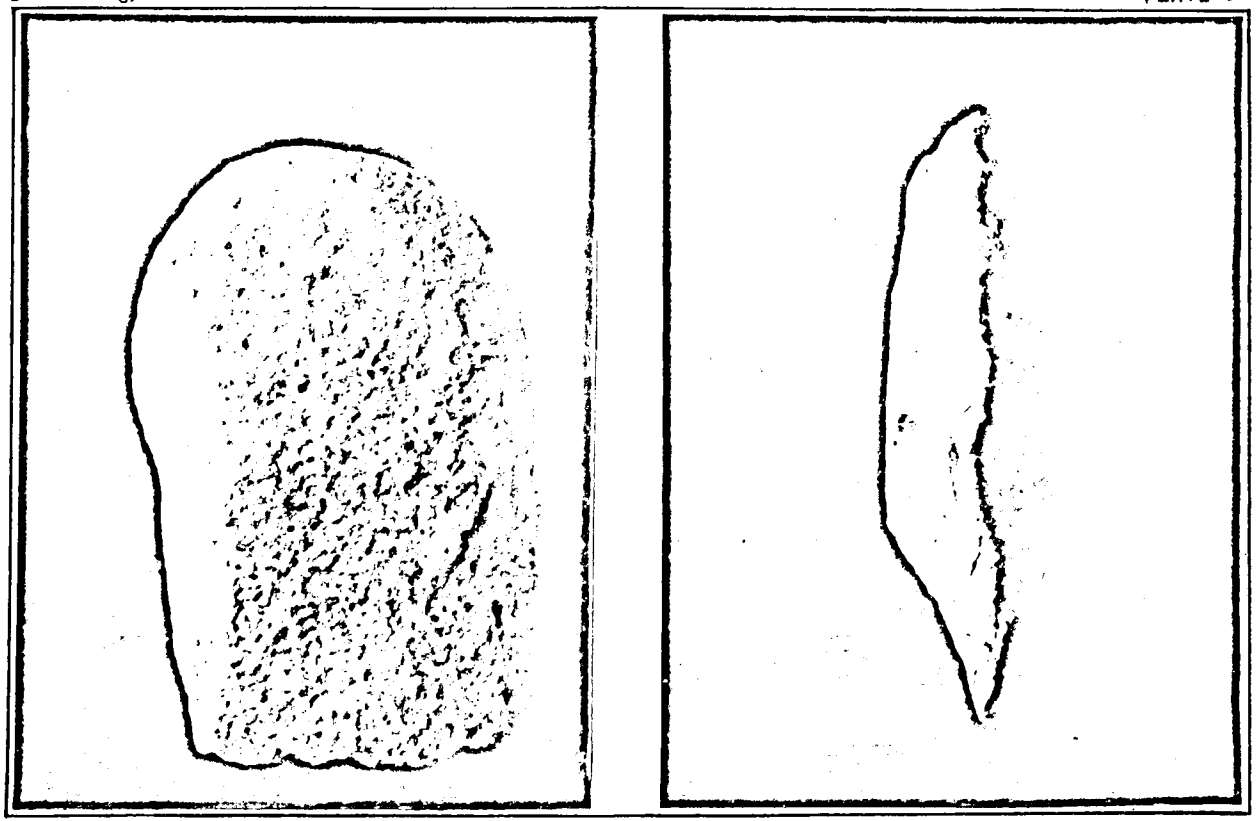
Photo-Print., Survey Office, Ma
1899

7. Blown Loess
6. Loess-like silt
5. Implement Shingle
1. Shingle, sandy, locally. ferruginous.
4. Shingle
2. Calcareous conglomr.
x Position of axe washed out of bed 3.



PALÆOLITHIC AXE FROM THE LOWER ALLUVIUM OF THE SABARMATI RIVER

and had the satisfaction of finding two more implements of the pointed oval type, both evidently derived from the same shingle bed as that on which I had found the worked flake the day before. The place where I found these implements is easy of identification, for it is exactly opposite the small, but conspicuous, riverside temple belonging to the Ahmedabad village of Sadolia. The relation of the implement-bearing shingle bed is clearly shown in the accompanying section (Plate IV). The axe of which I give two figures in Plate V. was made out of a coarse gritty quartzite of greyish white colour with dirty pinkish mottlings. It measures 6¾ inches in length by 4¼ in width and 2 in extreme thickness. It is slightly waterworn, which shows that it must have been rolled some distance before being imbedded in the shingle. From the shape of its butt-end, which has an almost sharp worked edge, this implement was quite unfit for use without having been fitted with some sort of handle. It would have been impossible to have dealt a heavy blow with it without greatly injuring the unprotected hand.

Pedhamli section.

The second locality, where implements were found, is Pedhamli, a large village 21 miles further up the Sábarmati, where a precisely similar shingle bed is exposed on the bank of the river in the section referred to before (page 68) and occupies a corresponding horizon in the alluvial series to that of the shingle bed in the section just described. The implement here found, a very shapely narrow pointed oval, 6" long, of coarse brown gritty quartzite, lay exposed on the surface of the shingle bed, out of which it had been washed by rain action, close to the little footpath which runs from the south end of the village down to the water's edge. The implement shows signs of having been rolled slightly before being imbedded in the shingle conglomerate. Like the axe just described it has too sharp an edge all round to have been used in the naked hand as a mere "root-grubber," and was doubtless made to be fitted with a handle of some sort.

Gullies cut in the river banks.

One of the most remarkable features of the alluvial tracts in Gujarat, and most especially in the valleys of the Sábarmati, the Mahi and the Watrak, is the formation of deeply excavated narrow gullies opening into the deep valleys of those rivers. These gullies, which form regular

fan-shaped labyrinths, cut up the country near the banks of the rivers in a remarkable way and often render direct access to the river bed very difficult or impossible, owing to their great depth and steeply scarped sides, which frequently compel the making of great circuits, to reach given points within the great plexus of ravines. So great are the difficulties, offered by these complicated networks of ravines, that in various places, especially along the banks of the lower Mahi, some villages standing on some of the small plateaus remaining centrically in the plexus of ravines, had with the help of very slight extra fortifications such strong defensive positions that the inhabitants, presuming on their impunity, became professional freebooters and plundered their more peaceable neighbours in the open plain country, till put down by the strong hand of the law when British power came into ascendancy.

This gully formation is mainly due to the action of heavy rains on the surface of the great loess formation which covers so large a part of the northern division of the state. In the southern part where the general surface is composed of the more tenacious black soil, the gully systems, though not absolutely absent, are developed to a far less extent.

There is a distinct and necessary connection between the depth of the river beds and that of the tributary gullies opening into them, for where the alluvial cliff banks of the rivers are lofty, the gullies are proportionately deep.

The gullies naturally supply innumerable sections penetrating deeply into the old river alluvia, but few of them are clear and distinct, which is due to the great quantity of rain wash that spreads over and obscures the lesser slopes and even the steepest surfaces where vertically, or so steeply, scarped that they are clear of vegetation. Innumerable small landslips, and in many places thick vegetation, whether grass or leafy brushwood, tend to obscure the gully faces so much that, in the absence of strong contrasts of colour or texture, in very many formations, they cannot be easily identified *en passant*. Similarity of mineral constitution of many of the beds exposed and the almost universal absence of fossils renders it impossible sometimes, and generally very difficult, to determine the existence of definite stratigraphical horizons over large areas.

As a rule it is only where fresh cliff falls have taken place that a perfectly clear and distinct surface is disclosed. As already mentioned the loess is remarkably free from organic inclusions which are so common in the loess of other countries, but in many beds of it, especially in the lower ones, there is a great deal of concretionary limestone in the form of gravelly kankar.

In some places the kankar appears in stalky or pipe shaped sticks which, in certain cases certainly, are calcareous casts of the roots and rootlets of shrubs and bushes which must once have grown there. These are in other places replaced by accumulations of nodular kankar which furnish the material used for burning into quicklime.

The really valuable and instructive sections seen of the alluvial rocks are very few and far between, but a few are deserving of description and these are found enumerated below.

Section at Saroli.

One of the best and clearest sections of the alluvium of the Sábarmati is exposed just inside the valley of the little Saroli nullah 4½ miles East of Vijápur, in the little tongue of Baroda territory lying east of the river. The combined action of the flood waters of the river and nullah have here cut the alluvium into a steep cliff about 75′ high in which the following series of formations is exposed:—

15.	Loess, pale loamy	?
14.	Do. reddish	3′— 5′
13.	Loam, lumpy, with much kankar	1′— 1½′
12.	Gravel, mottled, pale, ferruginous	3′
11.	Loam, lumpy, with much kankar	1½′— 2′
10.	Gravel, pale ferruginous	1½′
9.	Loam, lumpy, with much kankar	4′— 5′
8.	Gravel, pale ferruginous	2′— 3′
7.	Loam, lumpy, with much kankar	3′
6.	Gravel, pale ferruginous, falsebedded	3′— 4′
5.	Sand with much kankar, pale coloured	3′— 6′
4.	Clay sandy, with kankar, buff and white	6′
3.	Clay, mottled grey	?
	(Talus hiding base of 3)...	10′—12′
2.	Clay, white and pale purple mottled	4′— 5′
1.	Do. white slightly mottled	4′
	Water of Saroli nullah.	

The entire thickness of the loess is not seen in the section and must be very much greater as the ground rises rapidly and to a considerable height away from the river. The beds appear to be approximately horizontal and no organism of any kind was observed in any of them.

Nature of the gravels.

The gravels of the Sábarmati alluvium are chiefly composed of quartz and quartzite pebbles derived from the granite and Champanir rocks occurring to the N., N. E. and E. Many of the gravels near the base of the alluvium in the upper reaches of the Sábarmati show a bright rusty red colour and at a distance look much like poorly ferruginous laterites, into which indeed they would graduate of slightly more ferruginous. Such a gravel is specially well developed in the base of great alluvial cliffs S. of Mahuri to be described below.

The high loam cliffs in many parts of the Sábarmati valley, especially where not too much cut up by numerous lateral gullies, not unfrequently give rise to bits of scenery that are really very picturesque and pleasing though on a moderate scale only; indeed, the gorges cut by the river in places almost deserve the Spanish name of "Cañons," and afford a refreshing contrast to the general monotony of the interriverine plains.

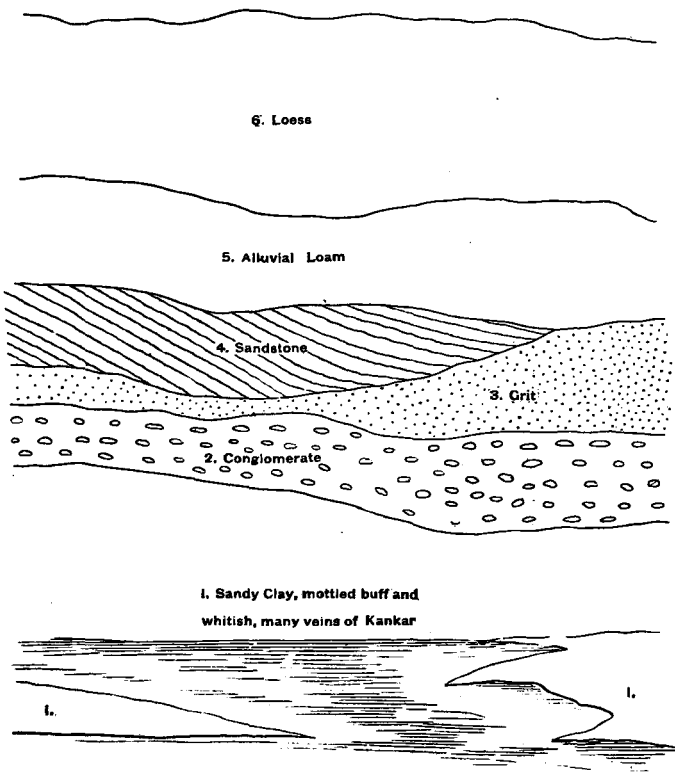
Reaches of the Sábarmati.

A few examples of the finer bits of river scenery deserve mention such as the views up and down the Sábarmati from the top of the river bank at Sádra. The sigmoid reach of the river at and above Madhaogát north of Sádra is a very charming bit of river scenery and the lower part of the reach affords an exceptionally good section of the alluvium.

Madhaogát section.

About half a mile South of the village is a section in the river bank which gives a fairly typical illustration of the rocks here composing the alluvial series and a diagram of which is given in Plate VI. The sand stones, grits and conglomerates underlying the alluvial loam are grey or drab in colour and much falsebedded in parts and ill-consolidated generally. The basement bed is mottled buff and whitish sandy clay, fairly hard and much permeated in places with kankar in veins and occasionally in nodules. The clay is fairly hard and resists the erosive of the river better than the sandstones and conglomerate. The cliffs at the point where the section was taken is from 50 to 60 feet high, and shows the following set of beds :—

Loess.
Alluvial loam.
Sandstone.
Grit.
Conglomerate.
Mottled clay.



SKETCH SECTION OF PART OF THE LEFT BANK
OF THE SABARMATI, S. OF MADHAOGHAT
CLIFF VERTICAL 50' TO 60' HIGH.

R. B. FOOTE del.

Reg: No. 4797
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Photo-Print., Survey Office, Madras.
1899

As will be seen in the section the bedding of these several formations is very irregular and shows that they were deposited by a river with a strong and variable current.

Shingle beds.

The shingle seen in the Sábarmati in the northern part of the Madhaogat reach consists mainly of concretionary sandstone. Pebbles of laterite, quartz and quartzite are not common, and very few of trap, or agate, were seen. Granite, gneiss and schist pebbles were locally altogether wanting tho' common enough higher up the river. The river sand at this particular spot was grey with silvery mica and contains also a quantity of comminuted garnet, which gives a very pretty reddish tinge to the crests of the wind-ripples in the dry river bed.

Where the river currents are strong enough to move coarse shingle the results are shingle banks which unless they have a clayey matrix afford no support to vegetation and remain barren, but where they have the clayey matrix they become covered with sedges and grass and bushes, such as tamarisk, and go on increasing by checking the currents of minor floods and causing them to deposit their sediments which thus gradually raise the banks or, if in midstream, become islands.

Present action of the rivers.

The action of the rivers of Gujarat at the present is far more destructive than constructive, at least in their upper and middle courses—the extent of the depositions they now form or have accumulated in recent times is extremely small when compared with the vast quantity of material they carry down when in flood. The deposits they form are mostly fine loamy clays with sandy partings forming together very fertile patches of alluvium.

Reaches of the Sábarmati.

From the Madhaoghat reach upward the river shows many picturesque reaches as the alluvial cliffy banks attain to considerable height rising frequently from 100 to 150 feet above the water. Even greater heights are met with here and there. The two reaches formed by the great bend of the river south of Lakrora are especially to be noted. On the west side of the upper reach is a fine line of cliff from 60 to 130 feet in height extending for more than 1½ miles. The Sadolia reach (2 miles further up stream) on the western bank of which are the shingle beds which yielded the very interesting palæolithic implement before referred (page 86) affords many very pretty bits of scenery.

Mahuri cliffs.

Still further up the bold cliffs on the right bank of the river at Mahuri are strikingly picturesque, and from the old temple of Koti Ser, on the top, a fine and fairly extensive view is obtained over the gently rising plain between Parantij and Ahmednagar.* The temple cliff is 150 feet high and very steeply scarped—much of its vertical river face being formed of hard kankarry loess which has great weather resisting power.

Reaches above Mahuri.

The two reaches above Mahuri may be described as pretty but are not specially remarkable except at Aglod where the river bank is cut into deeply by gullies. Above them the river scenery is affected chiefly by the eocene laterities and sandstones and still higher up by the association of these with the underlying granite, the alluvial conglomerates and the loess having thinned out very greatly.

Reaches of the Wátrak.

Similar in character to the scenery of the Sábarmati is that met with in the Wátrak which flows past and through the irregular patches of Baroda territory forming the

The Bokh valley.

* Time unfortunately did not allow of my leaving the Baroda territory and crossing the Sábarmati into the Parantij taluq to visit the very interesting old channel, locally called the Bokh river, which runs N.—S. past Parantij, and the origin of which has given rise to some discussion among the Bombay geographers, the literature of which discussion I have unfortunately been unable to look up, but it is impossible to study the physiography of this curious old river bed, if river bed indeed it be, as shown in topo. sheets 5 and 6 without coming to the conclusion that it was not formed by any change of course southward of the northern rivers, the Sábarmati and Háthmati, as they flow in channels far too much below the level of the Bokh channel for any possible floods in either of them to have risen over their banks and cut the now abandoned channel. The Khari river to the east of Parantij flows also at too low a level to have been capable of forming the Bokh by any possible flood causing it to change its course temporarily. By what then was the Bokh channels formed?

Only one likely explanation presents itself to my mind and that is that the Bokh valley is not a true river channel but rather a long depression formed by the piling up by the prevalent westerly winds of a long North to South ridge of loess which by barring the old drainage of the country into the Sábarmati formed a series of long jhils (lagoons) along its eastern flank which received the drainage of the country of the watershed between the Bokh channel and the Khari river. Two of these jhils remain; one at, and the other a little to the N. W. of Parantij town. Signs of a third and fourth jhil in the shape of swampy tracts are indicated on the map within the first two miles of the channel of the town. The drainage of the Bokh valley which is 12 miles long is to both North and South, starting from a point pretty nearly half way between the two ends. The northern end opens by a side gully, a couple of miles in length, into the Sábarmati just a mile, or so, south of the junction with the Háthmati, while the southern end opens into the Khari just a mile above the northern frontier of the Dehegam taluq (Baroda).

eastern side of the Dehegam taluq. Owing to the great height of the banks and the lesser width of the river bed some of the views on the Wátrak are even more striking than those on the Sábarmati above referred to. Reaches of the Wátrak noteworthy for their real beauty are those of Atarsumba, Punádra, Baria, Wagjipura and Mandwa. In all these the alluvial and loess beds alone are concerned—but in the Paorimoti reach the gorge cut by river through the eocene lateritic beds is much enhanced by the overlying loess which shows a steep scarp rising fully 50 feet higher still. The palm for beauty must be given to the Punádra and Baria gorges which form a most charming cañon, the Punádra end of which is crowned by a most picturesque little fort and village. At Atarsumba the town stands in a fine position on the top of a loess cliff which rises vertically about 150 feet from the river bed.

The Majham river shingle.

Judging by the much smaller depth to which the Meswa and Khari have cut their channels into the alluvial formations, the conclusion is inevitable that they have been at work for a very much shorter time than the Sábarmati and the Watrak, and especially must this have been the case with regard to the Khari which flows through a very shallow channel, a far shallower channel indeed than those cut by many other much smaller and shorter rivers to be seen in this portion of Gujarat. In the Sábarmati the channel cut is frequently over 100 feet deep and in parts as much as 150 and even 200 feet in depth. In the Watrak the depth of the bed runs from 80 to 150 feet in depth. In the Meswa, on the contrary, the average depth is from 20 to 30 feet, and a depth of 60 feet is only exceeded in three places where 70, 80 and 100 feet respectively are reached. In the Khari, the depth is much smaller still and rarely exceeds 12 feet, while the greatest height of the banks attains only to 15 or 20 feet, and this in but very few places, although the formations cut through are nothing harder than loess and kankarry loam.

Relative ages of the Sábarmati and its tributaries.

Proceeding south, the scenery of the Mahi valley, except in its lower reaches near the great railway bridge, is mainly conditioned by the presence of great quantities of the cretaceous Deccan Trap, and such is the case in most parts of the valleys of the tributaries of the Mahi on the left side of the river, *e.g.*, the Mesri, the Goma and the Karad.

Alluvium of the Mahi valley.

The Dadhar and its tributaries.

The Vishwamitri, Deo and the other tributaries of the Dadhar all flow, as a rule, in channels which in proportion to their size can only be described as deep, banks of 20 to 30 feet high being commonly met with along the smaller rivers, while in the larger ones, such as the Deo (Dev), the Dadhar itself and the lower reaches of the Viswamitri, the channels have often been cut to depths of from 40 to 60 feet.

The Nerbudda.

The Nerbudda has, in proportion to its size, cut less deeply into the alluvium than the Sábarmati and the Watrak, its banks rarely showing a height of 100 feet and exceeding that height only in the Sinor reach, at the apex of which an elevation of the right banks of 130 feet is recorded in the Topo. sheet (31), but the channel of the river is actually and proportionately far wider, and during flood times much of the adjacent country must be overflowed. The lateral oscillation of the river is on a much larger scale than in any of the other rivers.

The Orsang, Unch and Heran.

The principal tributary of the Nerbudda from the north is the Orsang, the lower part of the course of which runs chiefly through Baroda territory where it has eroded for itself a fairly deep channel through the alluvium, and in this respect stands fourth in rank, occupying a position between the Nerbudda and the Meswa, but it is not equal to the northern rivers in the quantity of water in proportion to the size of its channel and the scenery in the different reaches is generally tamer. The tributaries of Orsang, the Unch and the Heran rivers are of dissimilar character, the former being a narrow sluggish stream flowing in a deep channel which oscillates greatly, the latter a wide rapid river which oscillates but very little and shows banks of very unequal heights in different parts of its course. In the Unch the banks are less frequently cliffy than in the Heran, for which reason it affords many fewer sections of the alluvial beds it cuts through. In both rivers the upper courses flow in much shallower channels than do the lower ones. The Heran receives many fewer tributaries than does the Unch.

Prevalence of gully systems.

Owing to the great thickness of the loess formation underlying the superficial deposits, generally an intensely black regur or cottonsoil, the banks of the Orsang and its tributaries are much cut up by great gully systems, though

not to such a great extent as the banks of the Sábarmati, the Watrak and the lower course of the Mahi.

The Aswan and Men.

Of the two small rivers which fall into the Nerbudda above the Orsang, the Aswan and the Men, the former does not touch Baroda territory, so needs no further mention, and the latter within the limit of the Amroli Mahal (a sub-division of Sankheda taluq) follows a very oscillating course with a wide channel and rather low banks for its size. To the north of Amroli village it reveals a remarkable bed of shingle of extraordinary coarseness, the individual pebbles being of great size, few of them smaller than a large cocoanut, and many very much larger, regular boulders in fact. The thickness of this bed is not shown in the river section, and its surface extent is uncertain owing to the great sheet of black soil which covers the face of the country, but it certainly occupies an area of several hundred acres north and north-east of Amroli village. All the boulders observed in this giant shingle bed consisted of trap rock and the very great majority of hard basalt.

Boulder shingle at Amroli.

The Kim.

Turning to the rivers flowing through Baroda territory south of the Nerbudda, the Kim offers but little to write about. Its course is very oscillating, and it flows in a generally rather sluggish stream between moderately high banks, and affords very few noteworthy sections of the alluvial beds, as the banks are generally grass-grown and very rarely cut into cliffs of any height.

The Tapti.

The Tapti, which flows in a wide channel with generally shelving banks of no great height, shows only one really interesting alluvial section which occurs at the town of Kamrej on the left bank of the river.

Kamrej section.

The combined action of the river and of the streams forming the gully system south of the town have formed a small island with very steep cliffs on the east and west sides, the latter of which shows especially clear sections of the alluvium about 70 feet high. The rock exposed is entirely loam, which near the base is well bedded, the bedding being indicated by laminæ of small kankar nodules. The island rises several feet higher than the surrounding country and commands fair views up and down the reaches of the Tapti.

The alluvial beds in the river banks higher up the river in the Songad taluq are rarely cliffy, being too loosely sandy in character to form steep scarps. In many places the sand consists so largely of magnetic iron as to assume a grey or even blackish hue. The sand in the river bed is also frequently very rich in magnetite so much so as to raise the question as to whether it might not be worth collecting the sand on a large scale for the manufacture of charcoal iron in the forest tract along the river. This matter will be found more fully treated of in the chapter on Economic Geology.

The detritus carried down by the Tapti consists so largely of comminuted trap rock that the sand in the lower reaches of the river even where not largely mixed with black magnetic ironsand is very dark in colour, and to the N. of Kamrej the westerly wind has piled up a small group of blown sand hills of very dark colour. This dark sand was blown up from the broad surface of the Kathor and Kamrej reaches, which are to a great extent dry in the hot weather.

Further up the river in the Vájpur reach the shingle banks show large quantities of agates mostly comminuted, showing that there must have been great destruction of amygdaloid trap flows higher up the valley of the river.

The Mindhola river alluvium.

The Mindhola river in its lower course bordering and traversing the Palsana taluq is, on the whole, a rather sluggish stream cutting through the alluvium with numerous oscillations and with shelving rather than cliffy banks in which the beds cut through are ill-displayed. The prevalent formations are pale or reddish loams, and the banks not unfrequently attain elevations of from 40 to 60 feet above the surface of the river.

The Purna alluvium.

The Purna is a more rapid river and has a wider bed and higher and more cliffy banks which often attain to 70 or 80 feet in height, but in which no sections of special interest were observed except in the tidal reaches close to the B. B. and C.I. Railway. The tide runs up the river for a distance of several miles above Nausari, and at spring tides during the rainy reason light sternwheel steamers could

doubtless navigate the river as high up as Moha (Mahuva) and carry back to Nausari building stone and road metal, from the local laterite formation both of which would be of great value to the people of that thriving little town.

The Tokarwa river, the principal tributary of the Purna from the south, and its minor contributories, are eminently alluvial rivers flowing in relatively deep narrow beds which make very numerous oscillations. The streams being sluggish their banks show few cliffy scarps and offer therefore few sections in which to study the alluvial deposits. No important sections were met with by me, but my examination of the alluvial deposits was necessarily a very incomplete one, as the older and economically more valuable rocks rightly demanded my attention to a much greater extent. The exposures noted were all loam resting on gravelly beds, and in the absence of all organic remains singularly devoid of interest. The Tokarwa alluvium.

In the Ambika and the Kaveri rivers and their tributaries, the two most southerly traversing or skirting Baroda territory, no alluvial sections of importance or interest were met with. The Ambika and Kaveri alluvia.

The paucity of organic remains in all the alluvial deposits, as far as my exploration went, is very remarkable and very disappointing, for in such extensive alluvial deposits and such splendid sections, as are afforded by the endless gully systems, one could not but anticipate making finds of great palæontological interest. With the exception, however, of the few mammalian bones above enumerated from the sands of the Orsang near Bahadarpur, and the palæolithic quartzite implements found in the gravels of the Sábarmati at Sadolia and Pedhamli nothing was found deserving of mention. Paucity of organic remains.

The coastal fluvio-marine alluvium.

The formations which may be confidently assigned to this section of the great alluvial series are exposed only to a very limited extent along the coast of the Gulf of Cambay at Umrat, in Nausari taluq, close to the Gaekwar's summer palace. They are much covered up to the west by the sand-dunes which bound the east side of the beach, between the mouths of the Mindhola and the Purna, and to the east by the general spread of black soil.

The rock seen to the east of Umrat village is a fairly

hard, rather dark coloured sandstone, full of shells and serpulæ of species now living in the adjacent sea.

The Gulf of Cambay is an extremely muddy sea owing to the immense quantity of sediment carried into it by the many rivers draining Gujarat and the east side of the Kathiawar peninsula, and to the many strong tidal currents which are constantly flowing backwards and forwards and preventing the settling down of the fine clayey particles held in suspension by the agitated waters of the Gulf. It is quite possible, indeed very probable, therefore, that many of the clayey beds further inland in the estuaries of the different rivers and exposed only at neap tide may be partly of marine and partly of fluvial origin, though unfortunately they contain no organic remains by which to determine their origin positively.

B. THE SUBAERIAL FORMATIONS.

The subaerial formations in Gujarat are chiefly represented by two great groups, the older of which is of æolian origin, or in other words made of materials collected and distributed by wind action. To this group belong the great blown loam, or loess, deposits so frequently and largely met with in the northern half of the State, and a few rather unimportant examples of blown-sand dunes. The younger group is the black soil (cotton soil or regur) which occurs very largely in the southern half of the State, and according to the most accepted views represents former extensive forest growths of which it is the remaining humus.

The Loam, or Loess Formations.

Loess hills.

The whole of the northern division of the State may be said to be covered more or less thickly by loess, which occurs generally in continuous flats often covered thinly with sand, but on which hillocks of similar loess have in many places been raised by wind action singly or in groups of varying size and heights. These blown loam hillocks as mentioned in Chapter I. (page 3) are grouped in clusters in different parts of the country, but a few are scattered about in isolated positions far away from the clusters. The principal clusters may be now mentioned again as they require some notice individually. They are as follows :—

a. A succession of loam hills of very marked character running E. or E. by N. from Sidhpur, and forming a band across the northern part of the Kheralu taluq, a distance of 22 miles with a width of about 6 miles.

b. A group of loam hills at, and to the S. W. of, Mehsana.

c. A large cluster of hills at, and around the town of Kari.

d. A very important band of hills beginning a little S. of Dungarwa railway station and extending some 10 miles to the N. and then trending another 12 miles N. E. by N. as far as Gothwa.

e. A band of hills increasing in size and number as followed northward from a point 5 miles S. of Vijapur to Karbatia and Undhai, a distance of 20 miles.

f. A small group of loam hills lying east of the Watrak river near Wagjipura.

g. A small but rather thick cluster of loam hills on the right bank of the Watrak river 2 miles N. W. of Atarsumba.

h. A group of rather scattered hills of large size lying between the Watrak and Meswa rivers about 10 miles to the S. W. of Atarsumba.

i. A group of scattered hills of good size lying westward of group "*h*" between the Meswa and the Khari rivers.

j. A quadruple linear group of loam hills running parallel with the bend of the Mahi river in the northern part of Sauli taluq, N. W. of Warsara, and trending southward as the river trends westward of Desar. Some of these are on or just inside of the western boundary of the Baroda State, others lie outside the boundary in Rewa Kanta.

k. A linear group of loam hills running roughly parallel with the Orsang river in an E. N. E. direction past the large village of Makni and extending up to, and a little beyond, the extreme N. E. corner of the Gaekwari boundary which there lies about 2 miles E. of Bodeli railway terminus.

l. A group of very low loam hills traversed by the B. B. C. I. railway in the cutting to the S. E. of the great bridge over the Mahi.

A small number of scattered loam hills occur remote from any of the groups above named, but which, with one or two exceptions described further on, are not worth referring to separately.

Position of Vadnagar.

The considerable elevation of the town of Vadnagar over the general plain is due probably to its having been built on such an isolated loess hill.

The questions of the origin of these widely scattered loam hills, and of the general loam plain on which they rest, are of considerable interest, and before dealing with them I should have liked to have had the opportunity of visiting the head of the Gulf of Cambay and the lower parts of the valleys of the Mahi and Sábarmati rivers, also the eastern part of the Kathiawar peninsula. It would also have been more satisfactory to have had greater knowledge of the directions of the prevalent winds. In the absence of the personal knowledge on these points that would have been so desirable, I must see if a careful discussion of the data that are available will not throw some light on the present shape and disposition of these interesting æolian formations which present features differing considerably from ordinary wind raised dunes.

Wherein the loess hills differ from ordinary dunes.

The principal point in which many of these loam hills differ from ordinary dunes is that their longer axes lie in very many cases parallel with, instead of, at right angles to the direction of the winds prevalent at the time of my examination of the country. The second noticeable difference is that they do not then present a long gentle slope to the wind and a steep advancing slope away from it, their sides are equally scarped, and the little drift that was taking place during the cold season, when I examined many of them, skirted the sides of the drifts longitudinally. During the earlier months of the cold weather the drifts was westerly and during the later months easterly. Were they heaped into shapes like those now shown, or are they typical dunes in a state of degradation?

The piling up of these loess dunes may of course in some cases be due to strong wind action tearing up bare parts of the loess plain generally, but it has also been caused by the carrying action of the wind bringing fresh material from the south-westward from the beaches and great sand-

banks of the Gulf of Cambay and the estuaries of the great rivers were opening into it. Whether fresh hills are being formed at the present day I have not been able to ascertain, but probably such accumulations are still being formed, though I had not the good fortune to be able to identify any such. The study of the course of formation of any such nascent hills should be carried on for several years and the phenomena observed communicated to the Geological Survey of India or one of the great geological societies for publication.

Inundation lakes.

A third special feature of the loess hill tracts in the Kari Prant is the formation of small inundation lakes, lying in hollows formed by loess hills and having no outflow. They are of small size, rarely more than a few hundred yards across and apparently quite shallow. The water contained in them is when quiescent quite limpid, and they are features of beauty in the landscape. Whether any of them retain water all the year round I could not ascertain personally, but many certainly do not, as they are not indicated on the topographical maps. I saw and examined a good many such lakelets in the loess country and a further number of tanks or ponds, which are shown on the maps without the indication of any "band," or dam, which in other cases is most unmistakably drawn, are doubtless true inundation lakes due to the formation of small basins by the special distribution of the loess dunes which have dammed the courses of the local streams. A considerable cluster of these lakes is shown in sheet $\frac{106}{78}$ in, and to the east of the Kari group (*c*) of loess hills; it was not in my power however to spare the time necessary to ascertain the true nature of each of these sheets of water. Two may be specially named in the above group, the Dungri tank (of sheet $\frac{106}{78}$) east of Ghumasan and 1½ miles south of the Dangarwa station (B. B. & C. I. Railway) and a large pond (or lake?) half a mile N.W. of Chhutur. North of the Ghumasan lake (Dungri tank) a line of similar ponds, or lakes, or jhils, extends northward some 10 miles among the loess dunes forming the Dangarwa-Wasai cluster. Similar jhils continue among the loess hills after the cluster trends to the N. E. Many of these are at times mere swamps and are shown as such on the maps. Several good examples of such lakes in

loess-enclosed basins occur in the northern part of the Kheralu taluq 4 or 5 miles N. of the town of that name. Others may be seen in the "*h*" and "*i*" groups of loess hills of the list above given. The *Baroda Gazetteer* states (p. 589) that there are no lakes in the Dehgam taluq; but this is a mistake; there is a very good specimen of a small one in the elliptical loess hill lying to the N. W. of Baora 8 miles east south-east of Ahmedabad, and several other very typical examples among the loess hills to the S. E. only a few score yards outside the Baroda boundary. The loess hills have a great tendency to enclose local sheets of water.

Blown loam hills.

A marked exception in colour from the generally pale drab colour of the blown loam hills is to be seen in the case of group "*j*," in Sauli taluq on the left bank of the Mahi, where the hills are of distinctly dull brown tint, but the loam composing them is not appreciably different in texture and composition to the ordinary type.

One of the most remarkable loam hills seen in Gujarat is that occurring 5 miles E. of Asoj outside the Baroda territory but continuous with the sandy loam hillocks occurring at Báska. It is the best example of the typical advance of the æolian deposition at right angles to the prevalent wind. The loam is moved nearly due east to within a distance of 1½ miles of Pavagad mountain and then stops short, its advance being apparently checked by the rebound of the wind from the great trap cliffs it impinges on. The eastern slope of the hill is much steeper than the western; the hill rises 150 feet above the adjoining plain, and is composed of brown loess in which I could not find any organism, though it is well displayed in several deep cut rain gullies.

Absence of fossils.

A well-known feature of the European loess formations is their very frequent enclosure of landshells in a fossil, or subfossil, condition. This feature is generally wanting in sections of the Gujarat loess: indeed the paucity of organic remains of any and every kind in the loess and alluvium is most remarkable, compared with the equivalent formations in the most southerly parts of the peninsula, but it must be borne in mind that Gujarat as a zoological province is extremely poor in its landshell fauna. Excepting a few large dark grey slugs crawling about the Kamáti bagh (park)

in Baroda, I did not, in Gujarat proper, in nearly three years come across a single living landshell, though constantly on the look out for them: and the list of species found in a dead condition was remarkably poor, poorer by far than in any other Indian zoological province I had previously worked in.

Sand Dunes, or Blown Sands.—These are among the most recent formations met with in Gujarat and are in various cases in process of formation at the present day. They are in no case of great magnitude or importance, nor are they of frequent occurrence. Only two occurrences of them are worth noting. They are firstly the line of dunes running along the coast between the mouths of the Mindhola and the Purna already referred to (p. 98) and a couple of ill-defined flattish sandhills on the left bank of the Tapti just north of Kamrej.

The coastal dunes show no special feature; they are composed of ordinary pale coloured siliceous sand, and in that respect differ from the local beach sand which is dark coloured. The change in colour is probably due to the sorting action of the wind in gathering up the quartzose part of the beach sand because of its lesser specific gravity and leaving the darker coloured and much heavier basaltic and magnetic iron sand behind.

In the case of the Kamrej dunes they are formed by the action of the strong S.W. wind, which begins in April, sweeping across the broad reach of the river in which owing to the lowness of the water a great spread of dark coloured (blackish) sand is exposed and lifting clouds of it and dropping them almost immediately on the river's bank.

Many little wreaths of blown sand are to be seen on the surface of the great loess area in the northern parts of the State. These, which are too small to be shown on the maps, are merely of local formation by the action of rain washing away the fine clayey or particles of the loess which bound the sand grains together to some extent. When thus released they are subsequently drifted about by the winds so prevalent in the hot dry weather.

Neolithic remains on the loess hills.

In only two cases, which are described further on, were human remains, or articles of human manufacture, found actually imbedded in a loess deposit, but many traces of man's having frequented the tops of the higher loess

hills were found in the Dehgam and Vijapur taluqs and also at various places along the tops of the loam cliffs skirting the different rivers. The great majority of these finds, though strictly prehistoric, are however devoid of geological interest, as they occurred only in made ground, and not imbedded in unaltered alluvial or subaerial deposits. To human agency alone must be attributed the occurrence, on the top of many of the loess hills, of numbers of small angular fragments of stone such as limpid quartz, chert, quartzite and agate, mostly bright coloured, evidently brought from long distances, as not a particle of stone of any sort or kind, very small concretions of kankar excepted, is to be met with on the loess covered plains intervening between the different hills or in the masses of the hills themselves. Some of these stones may have been wanted, to be shaped into "strike-a-lights" and others were converted into fine flakes required for various purposes, a few of which were also found, together with, in rare instances, cores of chert and agate resulting from the manufacture of flakes.

From the fact that these fragments of selected stones are in many cases accompanied by fragments of wheel-made pottery, of fair quality, it may be safely inferred that the people who brought both to the top of the loess hills were to a certain extent civilized and not rude savages.

The interval of time which lies between the imbedding of the palæolithic implements in the alluvium of the Sábarmati river, and the imbedding of the human bones, on the summits of the loess hills, which were heaped by wind action on the top of the river alluvia, must have been, historically speaking, very great and even, geologically speaking, of some duration.

Human bones imbedded in a loess hill.

In one case only were human bones found in a loess hill. The hill in question occurs between the Meswa and Watrak rivers 15 miles E. by S. of Ahmedabad and lies just outside the Baroda territory 1½ miles N. of the Baroda village of Kaniel. The bones included the calvarium of a skull and the mandible with a number of teeth of both jaws. The bones were found at the apex of the hill which is a big one (more than 100 feet high over the adjoining plain) embedded in the loess at the depth of about a yard and exposed by rain action and greatly comminuted *in situ*. The molars, and all the teeth indeed, had been greatly worn down by use on some very coarse diet. The bones were not mineralized.

CHAPTER IX.

ECONOMIC GEOLOGY.

THE mineral resources of Baroda State were but very little known when the survey was entered upon. The results obtained showed that the State was richer in valuable mineral than had been imagined, but in a country of which the vastly larger part is occupied by great alluvial and subaerial flats and in which old crystalline and metamorphic rocks, in most countries the real source of nearly all metallic wealth, occupy only a few score square miles of space, great store of gold, silver, copper, lead and other metals was not to be expected. The real wealth of the State lies in the rich soils which cover by far the larger part of it and in the industry of its husbandmen and herdsmen.

Want of roads.

As in all alluvial countries however the softness of the soil gives rise, during the rains, to impassable roads and for months together outlying tracts, especially in the black soil regions, are practically cut off from all intercourse with the great centres of population, while even in the finest season wheel traffic is in most parts immensely hindered by the dreadful state of the roads, or by their entire absence. How greatly this condition of things hinders intercourse and trade between different parts of the country can only be realized by those who have had occasion to travel much through the country in its present state. The opprobrium of want of roads, or disgracefully bad roads, applies to the whole province of Gujarat more or less. In crossing the bits of British territory lying between the many outlying tracts of Baroda territory the same evil is met with. The difficulty caused by the absence of road-making materials in most parts seems to have induced a state of despair and helpless acquiescence in the wretched state of roadlessness, and sufficient efforts have not been made to remedy this great and crying evil. Many sources of splendid road material had not been opened up at the time when I commenced touring through the country; they had not been sought for, thanks to the "laissez aller"

policy as regards road which seems to have prevailed in Gujarat from time immemorial and which still has possession of the minds of most of the people and higher officials, whose avocations do not compel their moving about in outlying tracts. The few railways that exist do but little to remedy the vast hindrance to general traffic over the country generally, indeed, they only accentuate the acute want of means of easy travelling in the districts in which they do not exist.

In 33 years of travelling in India, chiefly in the Deccan and the south of the Peninsula, I had never experienced such vile roads and was utterly unprepared for such a state of things as I found in Gujarat generally. In many parts there is no excuse for the utter want of metalled roads, for splendid material is at hand but not made use of, and in many other parts it is procurable at moderate expense if only a little trouble be taken to seek for it.

The state of the roads varies with the seasons according to the nature of the surface. The black soil as well known becomes quite impassable in the rainy season, a fact so patent that all travelling, and moving of produce is practically suspended for months where good hard high roads are wanting, and the rivers are unbridged, but a certain amount of agricultural carting and cattle-driving work must be done even after the rains have set in, and then the tracks become in a few days such fearful quagmires that they often do not recover from it during the dry season following but harden into ruts and lumps most destructive to the vehicles and most painful to man and beast going along them and utterly obstructive to all rapidity of movement. Such rough and deeply rutty roads are as great a hindrance to riders, for it is impossible with due regard to the horse's feet or the rider's neck to progress rapidly. The dangers of rapid riding over the deeply fissured black soil in the hot weather compel riders to stick to the tracks. The fearful dust into which cotton soil tracks are ground, where wheel traffic is heavy, adds greatly to the misery of man and beast travelling along them. This reaches its climax on certain so-called high roads where lax Public Works Officers wink at the rascally practice of road contractors filling up the ruts with black soil from road side pits

instead of proper metal. It does not require much imagination to conceive the state of such high roads after a good downpour of rain.

In the loam and sandy countries the roads are at their worst in the dry weather because the surface grinds so readily into deep dust, or sand, adding terribly to the labour of the draft animals and the discomfort of man by suffocating clouds of dust. The depth to which the ruts are worn down along the soft tracks, especially on the loam, is striking. On several occasions my tanga, a full sized one, was brought to a standstill by the axle catching against the ridges between the ruts!—an experience I had in no other part of India.

The vast difficulties of locomotion existing in many parts of Gujarat generally, but more especially along the valleys of the great rivers, have been and still seem to be but little regarded by the different governing bodies and this probably from the fact that the higher officers in their official tours keep along the beaten tracks between a few of the larger towns and avoid the outlying broken and trackless parts occurring in so many places along the river valleys and the wild hilly tracts as well. The special character of my work, however, compelled me to devote my attention most particularly to those very tracts and gave me an insight into the difficulties of travel such as few officials can, or do, gain, and it appears to me a duty to draw the attention of Government to such difficulties as they work great injury to the people inhabiting those roadless tracts.

One fact has impressed itself deeply on my mind, and that is that the great rivers of Gujarat are from the geological character of their position and nature of very much less value to the countries they traverse than rivers of similar size in many other parts of India. A study of the fine maps provided by the Topographical Survey will make my contention clear to many even who have not had practical experience of the difficulties of travelling along these river valleys.

Non-navigation of the rivers.

Excepting for a few miles in their lowest tidal reaches these rivers are not navigable, or at any rate not navigated! Only occasional ferry boats cross them during the rainy

season, or where a few permanently deep and unfordable reaches exist. Whether they could not be navigated to a considerably greater extent during the wet season is a question on which I cannot offer a positive opinion, my duties not having placed me near any of the larger rivers the rainy season. The question, however, is one deserving a great deal more attention than appears to have been devoted to it. In many cases, to be mentioned further on, if the rivers could be navigated with any degree of safety, large supplies of splendid stone, both building and road material, could be conveyed to the great centres at vastly cheaper rates than road, or rail, traffic can ever convey them.

From the great depth of the channels of most of the rivers, very little use of their waters can be made for irrigation purposes. The great depth of the channels similarly offer great difficulties to the construction of lines of traffic across the valleys, and the traders and travellers have in many places to make great detours to reach fords and practicable roads. There are numerous places in which the spending of a moderate amount by Government in cutting approaches through the loam banks to the river where good fords exist would be an immense help both to the poor local villagers and to the whole countryside for many miles around. Many old roads to fords, which have had to be abandoned, because ruined by the cutting action of rain torrents, might be restored, at no great cost to Government, and rendered available again to the great benefit of the surrounding villages.

Hindrances to traffic caused by the gully system

Add to the above difficulties the nearly equally great ones caused in many places by the extraordinary systems of gullies with long lines of steep and often vertical cliffs which are for miles together impracticable for horses as well as for carts and very frequently for foot passengers also. Many of these gully systems are extensive, covering several square miles with a perfect labyrinth of deep narrow gorges, which it is practically quite useless to attempt to cross in a direct line. Any effort to do so without a local guide generally results in disappointment and vain effort involving much waste of time and fatigue. In a great majority of cases it is far best not to attempt any short cut but to make whatever detour the map shows to be requisite.

It must be borne in mind that these steeply scarped, if not vertically sided, gullies vary in depth from a few feet up to 100 or even 150 feet, and in some cases on the Sábarmati river even exceed the latter depth considerably. Anybody with a reasonable amount of imagination will be able to realize to a fair extent the immense obstacle to progress along the river sides offered by these gullies. I have no hesitation in saying that they far more than tripled my labour along the beds of the deep channelled rivers, to wit the Sábarmati, the Watrak, the Meswa and the Malni.

Great destruction of river side land susceptible of check.

The destruction of valuable land by the unchecked cutting back of the gullies is very great, but much might be done to retard the erosive action by the use of small dams and dwarf walls, and by restricting the pasturing of great herds of cattle whose hoofs cut up the loam banks of the rivers and gullies to a startling extent. The growth of brushwood and grass along the tops and sides of the gully banks should also be encouraged to the utmost. Compensatory formation of low level alluvial flats takes place most rarely in the river valleys and nowhere on a considerable scale except in the estuaries very close to the sea, but there much more land might be reclaimed than is done at present if proper systematic process of "warping" were adopted.

Gain of land by warping.

The system of "warping" which has been employed with such immense advantage in England, *e.g.*, in the estuary of the Humber, consists in letting the muddy sea water run over the low lands at extra high tides and damming it back till it has deposited the bulk of the sediment it held in suspension.

Whether this process is in use anywhere along the littoral of Gujarat I am not aware, but I did not come across any signs of its adoption in any part of the fluvio-marine alluvial flat that I visited.

Mineral Resources.

The Mineral Resources of the State may be conveniently considered in five groups:—*A.* Metals. *B.* Building materials. *C.* Road making materials. *D.* Ceramic and glass making materials. *E.* Decorative stones.

A. METALS.

Of these only two were met with in Baroda—Iron and Gold, the former in fair and the latter in very small quantity.

IRON AND IRON-ORES.—The ores of this most important metal were in former times worked to some extent in different parts of the State, but the introduction of cheap iron from Europe has, as in so many other parts of India, completely destroyed the industry, or left it in a moribund condition, notwithstanding the fact that the indigenous smelters turned out iron of excellent quality.

The ores found to have been worked were of three kinds: hæmatitic, limonitic and magnetic to place them in the order of their importance. The occurrence of these several ores has already been referred to frequently when describing the geological formations of the situations in which they are met with. Thus the hæmatites and limonites of the eocene lateritic rocks supplied the ores worked formerly on a small scale in the valley of the Sábarmati, traces of which industry are to be seen near Phudera and at Vijapur, in the northern part of the state, in the shape of small accumulations of iron slag.

In the Kari Prant.

The iron industry of Atarsumba, in the south-eastern corner of the Kari Prant, which is not yet quite extinct depended similarly on the lateritic hæmatite occurring just outside the Baroda territory at Kapadwanj, in Kaira District, and smelted there. Whether any smelting was formerly done at Atarsumba itself is not quite clear, but certainly none is done now, nor as far as I could make out from my enquiries of the Atarsumba ironworkers had any smelting been done by their fore-fathers, but the iron was made at Kapadwanj and brought to them and by them worked up into swords, knives and cooking utensils.

Atarsumba iron industry.

The only articles I was able to procure of the Atarsumba iron workers were knives and frying pans of peculiar shape, but very good workmanship; so good that it is a pity they are not better known. The makers are poor and despondding and very wanting in energy to push the sale of their wares, but might be much assisted by the establishment of

a depôt for the sale of their manufactures in the bazaars of Baroda and the other large cities and towns in Gujarat.

The knives of which I saw three sizes are of one type, straight backed, very pointed and very broad at the base of the blade; the handles are rather short in proportion and made of pieces of bone rivetted on to a rather small tang. The frying or baking pans are rather shallow circular pans with two loop handles to lift them on and off the fire.

The smelting industry at Kapadwanj itself is, if not already extinct, quite moribund, its outturn being undersold by European iron imported in the far more convenient shape of well rolled bars.

A sword-making industry, on a small scale, exists at Delgam and turns out good blades fairly finished off, but strangely enough no hilts are made but the blades are fitted to old hilts taken from old and worn out talwars.

In the Baroda Prant.

In the Baroda Prant no smelting industry exists at present, but in the northern part of Sankheda taluq a comparatively large quantity of smelting was done at a remote period to which no history of any kind can be attached. The locality where this old industry flourished is just north of the little village of Samdhi, 9 miles N. E. by N. of Sankheda town. No traces remain of the furnaces used but a large area is covered with dark or black slag still rich in iron, amongst which I picked up a number of half-fused tuyères of very coarse gritty clay, and various fragments of extremely rich crystalline hæmatite derived from no body knows where. No clue whatever could be procured as to the locality whence this fine ore was brought, either by enquiries from the people locally or by examining the hilly country to the north which consists of the quartzite beds described above (p. 30) as forming the W.—E. ridges culminating in the Masabar (Mahabar) hill. Not the faintest trace of any hæmatite could be seen in the dry bed of the large nullah which breaks through the quartzite hills just N. of Achali. One or two of the hæmatite fragments found on the slag heaps showing signs of having been rolled, I made a very careful examination of the shingle in the nullah but without finding any trace of the ore. It is clear, therefore, that the ore must

The Samdhi Karkhana.

have been brought from a considerable distance probably because of the abundant fuel supply at that particular place at that time. Curiously enough I could not find any other traces of the old iron workers' existence either in the form of buildings, or in old pottery of special type left behind, though there are various other localities in Sankheda taluq where traces of prehistoric people remain in the shape of glazed pottery resembling somewhat the glazed pottery of the Southern Deccan which was made by people belonging to the early iron age. The Samdhi tuyères and some that I lately found in two old settlements of the early iron period on the banks of the Káveri east of Mysore are identical in shape, size and the coarseness of the material they were made of.

In the Velachha taluq.

Like the iron industries in the Sábarmati valley and at Samdhi the smelting industry in the southern division of the state is extinct and its former existence is only known by heaps of iron slag which are met with here and there. With two exceptions these old factory sites occur in the Velachha taluq at no great distance from the lateritic beds at Naroli Nahani which there form the base of the eocene (nummulitic) series (see page 72) and which yielded an abundant supply of moderately rich ore, a mixture of hæmatite, and limonite. The principal smelting site occurs at Vasravi, 9½ miles E. of Velachha, where extensive mounds of slag prove the former existence of iron smelting works on a large scale for India. Here again I could get no information as to the age of the industry and by whom it was carried on. No traces of any kind of habitation connected with the old smelters remain. No pottery of any kind was found on or near the slag heaps; but a quarter of a mile or less to the west the remains of a large funereal urn of fine black glazed pottery were found in the bed of the stream in which it had apparently been carefully buried. It was too much injured to be preserved, but the form and pattern remaining in some of the less spoilt fragments agree closely with some funereal urns used by the early iron-making people in Mysore, indicating a possible connection between the two peoples, and certainly a correspondence in degree of their respective stages of civilization.

The only other domestic implements found at Vasravi were parts of a stone cylinder and of a small stone platter with feet, both made of nummulitic limestone full of fossils. Judging by the highly weathered state of their surfaces, they must be of considerable antiquity, but they are not characteristic enough of any particular period to serve as basis for even a very roughly approximate estimate of their age archæologically considered. In the list of old iron making sites which I received from the Velachha taluq officials the villages of Charetha, Shaha and Dehgaria were set down, but at the first and last I could find no traces whatever of the industry and the villagers strenuously denied that it had ever existed in their borders. At Shaha the traces shown me consisted merely of a small heap of slag measuring a very few cubic yards in bulk; the industry had therefore been followed to a very trifling extent.

Iron sand in the Tapti river.

An immense quantity of rich magnetic iron sand is brought down annually by the Tapti when in flood, and the alluvium locally deposited on the banks of the river is full of it and so also the sand banks exposed in the dry season. The question has been mooted as to whether it would be commercially profitable to establish a charcoal iron-work at some convenient spot in the Songad taluq. The iron-sand could be easily collected by coolie labour, and stored at convenient places till the water is at a convenient height and then carried to the works in dug-outs which would save all the difficulties of land carriage. The storage of a large quantity before starting the works would be a wise precaution.

Proposed smelting works.

The separation of the magnetic ore from the siliceous sand and other comminuted minerals accompanying it could easily be affected by means of "vanners" or "buddles" as may be found most convenient to work either in the dry way or the wet way. It would be easy to adapt a magnetic train to the vanner which would carry out all the necessary separation yet more perfectly.

There are two principal difficulties to provide against and those are the unhealthiness of the Tapti valley during great part of the year, and the danger of an insufficient supply of charcoal if the forests be not conserved. The

former might be overcome to some extent by making a considerable clearance round the works wherever established and by not carrying on the work during the feverish season which extends from the end of the S.-W. Monsoon rains to the beginning of the hot weather in March; but a better plan would probably be to locate the works as far down the river as near where it becomes navigable close to Galha in Kamrej Taluq and to have a sawmill attached to them* to which the timber required could be rafted down the river during the rains while the iron sand collected could be carried down in boats together with the charcoal made in the forest out of the branches of the trees unsuitable for rafting. The waste from the sawmill would serve as fuel for the steam engines required to work both the sawing machinery and the blast of the smelting furnaces.

An additional advantage from locating the works away from the forest region would be that intelligent labour could be far more easily procured there than in a tract where the bulk of the very scanty population is composed of half wild jungle tribes.

Much might be done at no very great cost to improve the navigability of the Tapti especially at the head of the great rapid just below Kanja where rafts must have great difficulty in passing excepting when the river is in high flood.

In Kamrej Taluq.

Iron works were evidently located near Galha at some former time as much old weathered iron slag lies scattered about on the surface of the fields associated with fragments of antique glazed pottery in very weathered condition. The ore here was doubtless derived from the bed forming the southern end of the Naroli Nahani laterite ridge, the northern end of which supplied the ore smelted at the old works at Vasravi described above.

No iron industry was being carried on in any one of the

* The idea of establishing a sawmill close to the smelting works in the forest region of the Tapti was originated by Prof. Harold Littledale who communicated it to me when we were camping together in the Vejpur forests. The idea of locating both the iron works and the sawmill far down the river and well outside the jungle region, *e.g.*, near Galha I claim as belonging to myself.

taluqs of the Nausari Prant at the time of my several visits to it, and no old workings were reported to exist in any of them, Velachha excepted, nor did I come across traces of old forgotten iron works in them except those just mentioned near Galha in Kamrej Taluq and at one spot in Palsana Taluq on the little inlier of eocene laterite described in Chapter VII (page 81) and there the traces in the form of slag-heaps are so insignificant that it is clear the industry was only pursued for a very short time.

In Gandevi Taluq I met with no indications of old workings, doubtless because of the poverty of the lateritic iron ores occurring there.

Gold.

As already mentioned gold is the only other metal besides iron of which I met with any traces in the Baroda territory and unfortunately the quantity of the precious metal indicated was far too small to justify any attempt at mining for it. The indications referred to are the existence of a very small short vein of bluish quartz traversing a bed of chloritic schist seen in the high bank of the Heran river a little to the south-east of the small village of Sigam, 6½ miles S.E. by S. from Sankheda, which is described in Chapter IV. (page 37). The chlorite schist here forming the "country rock" belongs to the Champanir system. Samples of this quartz were assayed by Mr. Grey.

B. BUILDING MATERIALS.

Building stones.

In many taluqs of the State no stone of any description is to be found within a reasonable depth below the surface, *i.e.*, a conveniently quarriable distance; this is the case in all the western taluqs of the Kari and Baroda Prants, where the surface is formed by soft alluvial, or subaërial, deposits such as blacksoil and wind-drifted loam, or loess, as will be readily seen by reference to the general geological map of the State. In the northern half of the Kari Prant hard rocks are seen only in the banks and bed of the Sábarmati river and of a few small streams falling into it, while in the southern half hard rocks are seen only in the bed of the Watrak and in the outlying parts of the Atarsumba subdivision of Dehgam taluq.

In the Baroda Prant hard rocks are seen only quite close to the eastern boundary of the Sauli and Waghoria

talugs. In Sankheda taluq, which lies much more to the eastward, hard rocks are seen in many places and in great variety, but even here by far the greater part of the surface of the country is covered up by the soft alluvium of the Orsang and Nerbadda and their several tributaries.

In the Nausari Prant the hard rocks are exposed much more largely and are seen much nearer to the western boundary of the State which is here of a very sinuous character owing to the irregular shapes of the Broach and Surat collectorates and the territories of the Sachin chief.

The geological formations which yield building stones are the following, taking the oldest first :—

1. *The Archæan* system gives *Granite* at Virpur in the Kheralu taluq, and in the Sankheda taluq at Bhulvan and Bodeli and *Gneiss* at Bhadrali. *Crystalline limestone* also, and of many colours is found at Motipura, Harikua and Wadeli, all in Sankheda taluq.

2. *The Champanir system* is rich in valuable limestones (sub-crystalline) of many colours and much beauty which are exposed in the bed and banks of the Heran river in Sankheda taluq. The *quartzites* of this system which occur largely in the extreme north of Sankheda taluq at Achali and also in the Lachharras hill, 8½ miles E. by S. of Sankheda town, could furnish large quantities of extremely strong and hard flagstones if a demand existed for them. The quartzites could also be used as road metal, but would for that purpose be inferior in quality to the trap rocks whether from the dykes above named or from many of the basaltic flows and dykes in the Deccan Trap area.

3. *The Bagh beds* (*Marine cretaceous*) described in Chapter V, contain excellent building material known as the Songir sandstone (p. 43) from the large quarries in Sankheda Taluq. Large supplies of capital stone of the same age remain as yet untouched at Lachharras to the east and north-east of the Songir quarries.

4. *The Deccan Trap Series.*—A vast number of flows and dykes of hard basalt, dolerite and diorite are to be found in this series which could furnish much excellent and durable building stone, but most of it is hard to dress,

and consequently if it requires to be "fine dressed" it is much more costly than the free stones of the older Bagh series or the limestones of the younger overlying eocene or nummulitic series.

5. *The Eocene, or Nummulitic, system.*—Includes the laterites and sandstones in the valleys of Sábarmati, of the Watrak, of the Kim, Tapti, Mindhola, Purna and Ambika and nummulitic limestones in the valleys of the Kim and Tapti.

6. *The Fluviatile Alluvia* hardly ever contain any formations and the hardest seen which were sandstones sufficiently consolidated to be useable for any purpose except the rudest rubble-work in the valley of the Sábarmati.

7. *The marine alluvium* contains no useable rock excepting the "rag"-like shelly sandstone seen at Umrat.

8. *The subaërial formations of the loess and black-soil* were nowhere found in a sufficiently consolidated state to be of any use in building.

The localities where valuable building stones are now quarried or might be raised must now be enumerated in some detail beginning with the oldest rocks:

Virpur granite.

The *Archæan* system (1), of which the granites are the most important and most extensively found members. A fine show of a very handsome granite is exposed in the bed and banks of Sábarmati—to the east of the Baroda village of Virpur in Lat. 28° 45′ north, 10 miles E. by S. of Vadnagar. Immediately east of Virpur the river flows through a narrow gorge on the north-western side of which the granite forms a considerable boss, quite a small hill in fact, and rises well over the high flood level. It would be easy to establish a good quarry here with the object of raising this remarkable stone, which well deserves to be used for its intrinsic beauty. The rock is in colour a pale pinkish to greyish pink, due to the predominant component, an orthoclase felspar. The other components which make but little show are a bluish diaphanous quartz and biotite (black) mica. The rock is very hard and tough, and being very little cut up by joint fissures should be of great durability. The principal master-joint being a nearly horizontal one will be of great

advantage in quarrying. In texture this granite is moderately coarse and granular and will take a very high polish and then present a decidedly handsome appearance. It can be quarried in blocks of great size (see page 23).

The Orsang granite area.

The granite occurring in the bed and banks of the Orsang river at Bhulvan and Motipura shows several varieties and much of it is of very good quality and capable of taking a high polish and being used as a decorative stone of considerable beauty, and also as an ordinary building stone of great strength and excellent quality. As the railway between Bahadarpur and the Bodeli terminus runs along close to the granite area the stone quarried could be conveyed easily and cheaply to Baroda, or any place along the several railways in the State.

Motipura granite.

A very pleasing variety of granite is exposed to some extent to the west of the railway bridge over Motipura nullah in the first small stream falling into the nullah from the west. The opening of a quarry would show its quality at a depth below that to which the rock has been affected by atmospheric action in the surface. It is a pale nearly peach-blossom pink and pale green granite of very delicate colour, which if quarried below the line of weathering should take a high polish and form a very lovely material for panels and pedestals and other decorative purposes.

Bodeli granite inlier.

The granite at Bodeli is a coarse pale pinkish creamy very felspathic rock of good appearance but much weathered to a great depth, and therefore of but little strength, or durability, and a very undesirable building material. Deeper quarrying might remedy this by reaching a perfectly fresh and unweathered stage in the mass. As seen at the time of my visit it was greatly inferior in every respect to the Bhulvan granite, but then it was being quarried to a very trifling depth only.

Bhadrali gneiss.

A black and white gneiss occurring largely in the bed of the Orsang at Bhadrali would yield a very handsome stone, but had apparently never been quarried, and the same remarks may be made about a pale red felsitic looking rock occurring east of Tandalja 4½ or 5 miles S. E. of Bodeli station.

Of the numerous beds of gneissic schist exposed in the bed of the Unch river none had apparently been quarried, but none offered stone of valuable quality.

Crystalline limestones.

Many very interesting beds of crystalline limestone of very various colours occur in the Archæan area associated with beds of gneiss in a band north, north-west and west of the Bhulvan granite area. The most important of these is a good sized bed of dark green, white and pale pink mottled limestone which has been opened out by quarrying and has been cut and polished and yields a very beautiful marble. My old friend and colleague, Dr. Wm. King, late Director of the Geological Survey of India, pronounced it to be the most beautiful marble in India. When in England in 1894, I paid great attention to the marbles to be seen applied to decorative purposes in many of the great public buildings and also, as specimens, in the museum Natural History, South Kensington, but none in any way equalled in beauty this Motipura stone. The bed as exposed in the quarry, as seen at my last visit to it, is about 30 feet thick and dips vertically. Outcrops of it were traceable for many hundred yards in a W. S. W. from the railway direction, but beyond that its course is obscured by the thick pall of black soil which here covers the face of the country with hardly a break. The stone is one of such beauty that the course of the bed should be fully traced out by excavation.

Motipura green marble.

Harikua marbles.

Indications of a bed, or beds, of very handsome mottled green and green and white marble occur in the nullah which cuts the railway at the northern of the two single-arch bridges at Harikua, a hamlet a mile S. W. of the Motipura quarry. The extent and strike of this marble should certainly be determined by excavation which could be carried out fully at no great cost. It will be very interesting to ascertain the course of this marble to the westward especially. To the westward of the railway in the shallow depression formed by the stream from the N. W. other beds of good marble of drab pale brown and cream colour banded with white; these too ought to be exposed and their courses made clear. They may possibly be connected with the Motipura beds by a great curve which is hidden by the overlying blacksoil.

Beds North of Motipura quarry.

North of the quarry at Motipura other handsome marbles are to be seen close to the second culvert south of the Motipura railway bridge, but owing to the universal covering of blacksoil they were exposed only for distances of a few yards and should be uncovered to ascertain their size and courses. Beds were here noted by me of grey, greenish white, purple and cinnamon colour, and little further north near the south end of the railway bridge are other beds of cream coloured and grey purplish marble which are similarly much obscured by the blacksoil.

The most northerly limestone seen was a small bed, not very well defined, exposed about the centre of the cutting made to divert the current of the nullah from the railway embankment. This limestone, a piece of which was cut and polished, made a lovely pale purplish grey marble.

All these marbles are deserving of great attention and should be exploited as they may, if found in good quantity, become of great value commercially. Another bed of pale

Wadeli bed.

green and white mottled and clouded marble occurs in the bed of the Orsang a little to the westward of Wadeli. A specimen of this cut and polished under the care of Mr. R. F. Chisholm, the distinguished architect, proved of very great beauty and delicacy. Unfortunately this bed is exposed only when the river is very low and quarrying it would be a work of considerable difficulty and expense because of the strong flow of water. Both the eastern and western ends of the outcrop are lost sight of in a very few yards, and the basset edge rises only a couple of feet over the sand bank at low water. A deep cutting made in the loam cliff to trace, if possible, the eastern extension of the bed unfortunately failed to hit upon it.

Quartz.

Intrusive in the Archæan area and therefore conveniently to be mentioned here is a very large vein of milky white quartz of fairly pure character running northward from the right bank of the Unch river and well exposed for a couple of hundred yards. It extends apparently still further northward into the Vidvaswami Mata ridge (2½ miles E. of Sankheda town), but there loses its purity and good colour. This quartz is of sufficiently pure quality to be valuable for glass and china making.

2. *The Champanir system.*—The economically important formations in this system are limestone and quartzites. Slates of beautiful purple colour and good grain are also found, but unfortunately the cleavage is nearly coincident with the bedding that the slate and so imperfect that it cannot be trimmed into good roofing slates. The slates are exposed on the north side of the scarp of the ridge running parallel with the Heran river at Songir. They lie unconformably under the grits and sandstones of the Bagh series which are here so largely worked in the well-known Songir quarries immediately to the south. The quartzites of this system are of no great economic value, their extreme hardness rendering them unfit for fine dressing; still in places they appear as well flagged beds which could be easily quarried for flagstones and used with advantage for general building purposes. Where not disposed in flaggy beds they yield material fit only for rubble work. Flaggy beds are met with both in the quartzite ridge of Achali (pp. 5 and 30). On the western side of the two small quartzites knolls at Sihadra about a mile South of Wasna, on the Heran river, a bed of remarkably thin flagged quartzite is quarried to a small extent, the very thin flags which are between half an inch and an inch only in thickness being used as baking plates and locally also as whetstones.

Limestones in the Heran Valley, Sandara inlier.

The limestones of the Champanir system which occur in Baroda State are all met within the valley of the Heran river, where they are found to occur in very considerable quantity. They are exposed only in the bed and banks of the Heran river as shown in the sketch map (Plate I.) given above. The economically valuable beds exposed in the Sandara reaches of the river are the different limestones whose geological position is described on page 35. The variety of limestones here found is very considerable, the differences being differences of texture as well as of colour. To take the varieties in order from south to north. The first beds met with run nearly W.N.W. across the south reach at Sandara, and are thick and thin flagged hard compact (sub-crystalline) limestones having a high northerly dip. In colour they are pinkish and drab and are overlaid by banded grey-brown and buff beds. Towards the centre of the reach this set of beds makes a sharp curve to the south

and then to the east. Between these two curves the beds show much crushing and have been converted into a coarse breccia. Unfortunately the extent of the brecciation is but small, for it results in a marble of very great beauty especially in the reddish and warm buff-coloured beds. Where unbrecciated the limestone is very dense and compact and constitutes a first-class building stone of very considerable beauty. A very large quantity of it could be quarried in the river bed without any difficulty being experienced from the water as the central channel to which the river is restricted in the dry weather is a deep one. These beds extend into the right bank of the river under the loam formation and could easily be followed up there by quarrying. These limestones dip, as described at p. 36, under a series of green and brown schists immediately south of Sandara village. North of the village the schists are succeeded by thick-bedded blue-grey limestone weathering brown. This also is a good class building stone and occurs in considerable quantity. If well cut and polished it would form a handsome marble. Overlying this is a thick series of dark grey, almost black calcareous schists much disturbed and contorted and cleaved in parts, and this is overlaid by beds of black limestone with white veins of calcite presenting a very striking appearance. They are, however, too much weathered on the surface to judge safely of their value as marble, for it is uncertain how they would take polish. If found to be hard enough they would yield a strikingly handsome stone. Unless the proposed railway from Bahadurpur to the Songir quarries has been, or is to be constructed, the easiest way to carry these Sundara limestones to a market would be to stack them on the river bank in the dry weather and to carry them down the river in the rainy season, when the river is in moderate flood, either on rafts or shallow barges, which could deliver them close to the railway terminus at Chandod for conveyance to Baroda, or else take them on to the Bombay, Baroda and C. I. Railway at Broach, or to the bunder at Broach for shipments to Bombay and elsewhere by sea.

Achali ridge quartzites.

The quartzites of the Achali ridge, the northernmost extremity of the Sankheda taluq (p. 31), are fine well-bedded-thick flagged rocks which would lend themselves

well to the construction of great masses of masonry, such as foundations, dams and weirs, &c., but they cannot, owing to their great hardness, be easily trimmed, and would therefore be of less value for buildings requiring architectural detail or stones of small scantling. In point of quantity, they would offer a practically inexhaustible supply.

Quartzites of Lachharas hill.

Láchharas hill 9 miles E. by S. of Sankheda (p. 33) could yield a good supply of thinner flags than the Achali ridge, but the same difficulty exists with regard to their unsuitability for fine architectural and decorative work.

Sihádra knoll thin flag stones.

Quartzite showing flaggy structure of very unusual thinness occurs in small rocky knoll rising out of the alluvium of the Heran river close to Sihádra rather more than a mile south of Wásna (Sankheda taluq). The flags here vary in thickness from less than an inch to about an inch and-a-half, the average being a little over an inch, a great contrast to the flags seen on Láchharas hill will run from 4 to 6 inches in thickness, while the thick flags of the Achali ridge range from about ten inches upward. The thin flags of the Sihádra knoll are a good deal cut up by joints and attain to but small lateral dimensions. They are used locally for plates on which to bake chupattis and other cakes, and a small trade was said to be carried on in them.

The Sihádra knoll represents No. 16 in the list of the small inliers of Champanir rocks in the Heran valley given in Chapter IV. (pp. 31 and 39).

Songir slates.

Inlier No. 13 of the above series shows purple slates (p. 38) which are unfortunately not of good enough quality to yield roofing slates. They are badly cleaved and not sufficiently fissile to split up kindly. They could at best but be used as inferior tile stones, or very small flag stones.

The Sandia breccia.

A very beautiful decorative material could be obtained by cutting and polishing the handsome breccia forming some fine crags half a mile to the south of Sandia (Kundia of topo. sheet $\frac{184}{44}$) on the Heran in Sankheda taluq (see p. 41). This extremely hard and dense siliceous breccia shows two varieties of coloration; in the one the matrix is reddish and the included angular fragments white; in the other the matrix is white and the inclusions red. This

rock, which has a lovely porcellanous lustre and strongly resembles a jaspery quartzite, is one of the most beautiful breccias I have ever seen. It is extremely hard to break, and the only large piece I succeeded in procuring and sent to Mr. Chisholm to have cut and polished was, I fear, lost, owing to his severe illness which necessitated his sudden departure to Europe. At least it could not be found when I enquired for it before leaving Baroda for good. The stone is, however, worthy of attention because of its great beauty and rarity. It would make beautiful slabs or pillars.

3. *The Marine Cretaceous Series (the Bagh beds).*—The members of this series, with one very remarkable exception deserving of much notice, offer very little of economic value.

The Songir sandstone.

This one exception is the beautiful sandstone quarried at Songir on the left bank of the Heran river in the Sankheda taluq. This sandstone, which as already shown (p. 43) belongs to the Marine or Bagh group of the cretaceous rocks, constitutes a formation of very considerable economic importance, which is capable of being made of much greater value to the State than at present, if it were worked on a larger scale and on a systematic plan.

Wasteful quarrying.

At the time of my several visits to the Songir quarries they were being worked in a perfectly haphazard way, leading to great waste both of time and material. This was the result of the work being left in the charge of perfectly ignorant uneducated foremen, and of greedy but equally ignorant contractors. The waste arose from the system pursued of indiscriminate quarrying and breaking out stone anywhere they fancied without reference to the requirements of the future, and of piling up the quarry waste all around, instead of removing it out of the way to a distance where it could become no hindrance to the future extension of the workings. The result of this was that the surface around the pits became so covered up with waste material that the pits could not be extended laterally except at the cost of removing the huge waste heaps, which would be very considerable. To obviate this cost and labour, fresh pits were opened at some distance at places

which had not been covered by the waste heaps. The area of good rock thus obscured and temporarily wasted is very great, and if the present system is continued, the general surface will become yet more completely honeycombed by detached pits without any system, and the eventual cost of removing the rubbish, when quarrying in a civilized style has to be adopted, will be vastly and most unnecessarily increased. The difficulty and consequently the cost of raising the stone from the bottom of great numbers of small deep pits must be much greater than if one large quarry were established on the floor of which light tramways could be laid by which the stone raised and the waste could both be carried to convenient distances at far less cost of time and labour than by the little solid wheeled carts drawn by buffaloes, in use three years ago and probably in use still. I have no hesitation in saying that if a properly conducted quarry on a large scale were opened, far better results would be obtained both as to economy of working and production of far larger and finer blocks of stone suitable for high-class buildings, &c., fetching much higher prices. The surface of the sandstone beds was so greatly obscured by the waste heaps and scrub jungle that I could not in the time at my command arrive at a clear idea of the relation of the several beds exposed in the many different pits, nor of their number and general relation to the sandstone group as a whole. It was not possible either to form any safe conclusion as to their aggregate thickness, but it is doubtless very considerable.

Nature and color of the stone.

There is considerable variety as to the colour and coarseness, or fineness, of grain in the several beds; they vary from very fine grained to distinctly coarse grits. Prevailing colours are whitish at the western end of the quarry area, and reddish-brownish, or purplish, in the central part, while elsewhere drab or delicate creamy tints prevail. The darker beds are, as a rule, of coarse texture. The thin bedded purplish beds are largely quarried for hand-mill stones (querns) which are made of large and small sizes. They are carried to market on buffaloes and donkeys, the former carrying the larger and the latter the smaller sized chakkis. These being thus carried on pack-animals is doubtless because of the bad state of the roads generally

throughout the country. The want of a good road to convey this beautiful freestone to Baroda and other markets was lamented by Mr. F. A. H. Elliot, when writing the *Baroda Gazetteer*.

The thickbedded sandstones were being very little quarried at the time of my visits.

Besides the quarrying, stone cutting was also being carried on, and I noticed *inter alia* slabs, low pillars for verandahs and house fronts and cattle troughs of different sizes, but all on a rather small scale as compared to the possible sizes that could have been obtained, but probably the demand was only for small-sized objects, owing to the great cost of carrying large ones over the vile roads or rather tracks, which alone traverse the eastern part of the Baroda Prant, to which must be added the great difficulty of crossing at least two unbridged rivers of considerable size and with high banks—the Heran and the Orsang.

The principal markets for the Songir stone would naturally be in the State, those eastward of Baroda City being the towns of Sankheda, Bahadurpur, Dabhoi and Chandod. I am not aware whether, or no, the extension of the metre gauge railway from Bahadurpur to the quarries, which was being discussed at the time of my stay in the State and was studied by Mr. Lynn, the Chief Engineer, and Mr. Lynde, the Resident Engineer of the Ahmedabad division of the B. B. and C. I. Railway, has been carried out. If not, and there is no present intention of making this very useful line the question of the navigability of the Heran river during the rains is worth enquiring into, for the stone might be conveyable in shallow barges, or on rafts, as far as Chandod to the terminus of the Chandod branch railway, and thence carried into Baroda at less expense than it can now be carted to Bahadarpur, the nearest station on the State Railway.

It is not improbable that if the Songir stone could thus be shipped down the Heran and the Orsang as far as the Nerbudda, that it might be taken on yet further to Broach and even to Bombay, for in point of beauty it is far superior to the best Porbandar stone and probably equally superior in durability.

If these enlarged industrial projects are to be realized, it would be advisable for the State to create a monopoly in its own favour, and have the quarries worked for a time under European superintendence till a really well-conducted large quarry had been brought into proper working order and a useful set of quarry men trained up.

Nobody in Baroda State was capable of organizing such a well-managed stone industry, and it was thought that such an experienced manager might perhaps be procurable from the great marble quarries at Makrana in Jodhpur State, and with this object Mr. Lynn and myself were deputed to visit those famous quarries, but we found that they had been for centuries worked in the most unsystematic, slovenly and wasteful way, and that no one there could be trusted to teach the Songir quarrymen any better ways than those bad ones they were already following.

Large reserves of the sandstone.

Large reserves at present untouched of sandstone of excellent quality, much of it probably equal to the Songir type, occurs to the east and north-east of the quarries. The first of these two reserves occurs to the south-west of Parwata (Parwanta of the topo. sheet $\frac{44}{184}$) 3 miles eastward of the quarries, and the second is to be seen extending along the small valley stretching eastward from the village of Lachharas and 4 miles from the quarries. It will take very many years before the exhaustion of these admirable freestones need be dreaded, even if the consumption of them increases very largely. Fairly good sandstones exist in the Amroli sub-division of Sankheda taluq in the long narrow band of Bagh rocks which stretches E. W. about 2½ miles south of the village of Amroli. Sandstones of fair quality belonging equally to the Bagh series may be procured, but in no large quantity, from the several outcrops of the Bagh beds in the Waghoria and Sauli taluqs at Dántaj, Sándásál, Kárachhla and in the Kun river south of Timba described above (Chapter V., pp 47—50). They are associated with pebbly gritty limestones which could also be utilized for building stone. The sandstones of Bagh age described as occurring at Nawagám (p. 42) would yield a useful building stone if they occur in sufficient quantity, but at present their extent is much hidden by surface deposits.

Reasons for little use of Trappean rocks as building stones.

4. *The Deccan Trap Series.*—The many varieties of hard rocks occurring in this widely distributed and important series have been most singularly neglected in Gujarat, the reason, as far as my observations went, being doubtless the greater cost which would have to be incurred in quarrying and dressing the stone as compared with that of building either in brick and stucco, or in the use of the easily worked freestones of the Bagh and Champanir systems. Very few examples of the successful use of basalts and diorites of the trap series came under my observation; the skilful and talented Hindu and Mussalman architects chose the Songir stone as seen at Dabhoi and Baroda, and the fine sandstone of Ahmednagar (N. of Parantij) as seen in the Rudra Mala at Siddhpur, and the great carved pillars for sacred swings at Vadnagar. The successful application in architecture of the free stones of the Champanir system are to be seen in the splendid mosques of the old and ruined city of Champanir, and the many noble buildings, palaces, as well as mosques which adorn the flourishing City of Ahmedabad. Another possible reason against the employment of the basalts, the commonest and most widespread of the Trappean rocks, was their dull and subdued colour which creates a "sad" and depressing effect on the eye, which is not to be quite overcome even by great architectural beauty and richness of decoration, as may be seen in connection with the vast and noble mosques and palaces and the grand walls and bulwarks of Bijapur and Gulburga in the Deccan.

Paucity of quarries.

Very few quarries of trap were observed anywhere and none of striking interest, but places where quarries might be opened if there were any demand for the basalts and diorites are infinitely numerous. In Chapter VI. I have enumerated a variety of outcrops of trap lying in the alluvial areas, which may become valuable when a demand for building stone or road metal springs up, which is sure to be the case in time.

Porphyritic trap.

A noteworthy variety is the porphyritic trap which occurs largely to the W. and S. W. of Vyara, which has been a little used as a building stone. The porphyritic structure is due to the presence of many scattered crystals (Phenocrysts) of sanidine felspar. They are almost

invariably twinned crystals of greenish white or drab colour, weathering nearly white. I did not see any of the rock in a fresh condition to judge of its hardness and susceptibility to take a high polish, but the probability is that if quarried at a sufficient depth it would do so and yield a handsome decorative stone.

Similar rock was noted in large spreads on the Nanchal dome plateau (p. 61), and forms also the flow which caps the Songad fort hill. A few of the coarser diorite dykes in the Songad and Vyara taluqs consist of rich green porphyritic rock which would yield splendid material for ornamental purposes on a large scale, such as pillars and pedestals for statues and great slabs. Unfortunately they occur in out-of-the-way parts of the country.

The majority of the dykes basaltic.

The great majority of the great dykes are basaltic and generally of a blacker tint than the basaltic flows they have cut through. They are also, as a rule, of more durable quality than the basaltic flows that they have risen through.

Granular trap rock.

A handsome green rock, very hard and tough, occurs in some of the large dykes in the eastern part of the Wajpur sub-division of Songad taluq, *e.g.*, the two dykes forming the south (875′) and north ridges of the conspicuous hill immediately north of the Nesu river, 3 miles E. by N. of its junction with the Arkkadi.

A similar granular trap, but of more blackish green colour, forms the great dyke rising into the 904′ Trig. Station hill 2½ miles N. by E. of Vajpur fort, which is now an abandoned ruin. This splendid dyke, which extends E. and W. for a distance of 25 miles, forms the summit point of the Nanchal dome 1,334 feet above sea level near Toran, and is one of the great features of the southern scarp of the dome.

Amygdaloid traps unsuitable for building stone.

Amygdaloid traps, as a rule, are quite unsuitable for building purposes, as they are wanting in coherence if largely vesicular and the vesicles be filled with zeolites as they generally are. They weather also much more rapidly than the more compact varieties. Even where the number of amygdaloids in the rock is small, they are apt by their more rapid weathering to form ugly holes in the surface of the dressed stone. In the rarer cases where the vesicles are filled

with siliceous matter in the form of small geodes of agate, these by their greater hardness render the stone difficult to dress evenly.

Amygdaloid traps only an indirect source of agates.

In no section of amygdaloid trap that I came across did I find geodes of agate of sufficient size in sufficient quantity to be of any economic value. It was only in agate gravel beds of eocene age that agates of any value were found, and such will be described further on.

Absence of Basaltic columns.

Columnar cleavage of the basaltic traps is so little developed in Gujarat that prismatic blocks (basaltic columns) of useful sizes were not found in any place that I visited.

5. *The Eocene* (*Nummulitic*) *System.*—The building stones found among the eocene rocks are not of great importance practically, but are fairly interesting and widely scattered over the country. Taking them in order of their economical importance, the following must be enumerated.

Sandstones at Phudera.

A small quarrying industry for sandstones of this age occurs at Phudera in Vijiapur taluq. The beds are exposed in the bed and banks of the Sábarmati and can be quarried in the dry weather only. The yield consisted of slabs and pillars, and a few drinking-water troughs for cattle. The stone, which is a rather soft freestone, is of pinkish drab or pale brown colours and very easily worked (see p. 67).

Grits bedat Virpur.

A singular hard grit formation described at p. 66, Chapter VII., as occurring to the N. by Virpur (on the Sábarmati) does not appear to have been quarried, but might be made to yield useful building material for rough purposes.

Hathuran sandstone.

The brown hard flaggy sandstone which occurs at Hathuran (near the 189 milestone on the B. B. C. I. Railway) in Velachha taluq is of very good quality, but unfortunately very little of it appears to remain, unless it is concealed by the surrounding black soil.

Clayey calcareous sandstones at Velachha.

The clayey calcareous sandstones occurring in the bed of the Kim river to the S. E. & S. W. of Velachha village might in the absence of better material be used for building purposes, but they are mostly rather wanting in cohesiveness. The same remark applies to the beds exposed in the Kim river above the Shettri reach, and in the Vasravi

nullah to the south of Charettra. Gritty sandstones show here and there on the surface near Dhamrod and Boridra to the north of the Kim river valley, but they are quite insufficiently compacted to be safely used as building materials. They often pass into gritty ferruginous gravels. Dhamrod and Boridra sandstones.

Other sandstones belonging to this system are the very coarse gritty beds exposed in the bed of the Tapti at Dhantwa and Karjan in Kamrej Taluq. They are ugly, rough-looking stones, but of considerable strength and presumably durable, but they do not appear to have been quarried, though they would be useful for rough buildings (see pp. 78, 79). Dhantwa and Karjan sandstones.

The well-known handsome shelly limestone of Tarkeshwar in the Surat Collectorate doubtless extends under the surface into both the valleys of the Kim and the Tapti. The rock is hidden, however, by the great and thick spread of black soil which lies on the watershed between the two valleys. As the limestone is a very valuable and handsome building stone, its extension into the Gaekwari should certainly be established by sinking trial-pits both northward and southward from the watershed. This was a point I had to leave unsettled by myself for two reasons: firstly, because I was greatly pressed for time, and secondly, because I did not care to keep my camp near Tarkeshwar longer than absolutely necessary, as cholera was raging there severely at the time of my visit in 1892. I noted, however, little outcrops of nummulitic limestone at Lindiad, Limodra and south of the Natu Pir tank (all in Kamrej taluq) on the southern slope of the watershed, and many surface traces of shelly limestone at and to the south of Nogama in the valley of the Kim and 4 miles E. of Velachha. The latter is of a buffy colour which reddens by exposure and becomes a very handsome stone capable of taking a good polish. Limestones.

A hard gritty shelly limestone of drab colour and containing nummulites occurs south of Dinod in Velachha taluq in small quantity, but it may be more is to be found under the surface. Dinod limestone.

Laterite is not often to be recommended as a building stone, but the highly hæmatitic laterite rock occurring at Laterite of Paori Moti.

Paori Moti on the banks of the Watrak river in the Atarsumba sub-division of the Dehgam taluq might be found valuable for building purposes, where a very choice stone is not a *sine quâ non*.

Laterite Dungar hill.

The laterite rock of Dungar hill in Kamrej taluq might be used for an inferior building stone (see p. 81).

Laterite in Moha Taluq.

The laterite rock which I have described (p. 81) as occurring at Kurel in Moha taluq in the cliffy bank of the Purna river would, I believe, from its strong resemblance to the laterite rock occurring at Kapadwanj in Kaira District (Bombay Presidency) lend itself well to being cut and dressed and largely used as in that town for many purposes. At the time of my visit no use was being made of the stone, but it might well be worked for the use of the people of Naṷsari, to which town it might easily be conveyed by boat down the Purna during the rains when the river would be easily navigable.

The laterite N. of Gandevi.

The four inliers of laterite met with in Gandevi taluq are fully described in Chapter VII., and all that need be said here is that they are quite capable of affording very large supplies of excellent material for the existing road from Gandevi to Billi Mora station and for the construction of several much needed new ones.

"Cement stones" at Velachha.

It has been pointed out above that the clayey sandstones exposed in the bed and banks of the Kim river in Velachha taluq furnish only a rather inferior building stone, being hardly sufficiently consolidated to make them strong enough to resist heavy pressure, but it is possible that they may turn out to be valuable in another way, namely, as sources for the manufacture of hydraulic lime, but for this they need to be carefully tested on a sufficiently large scale. It was pointed out on page 71 that locally these clayey sandstones are considerably ferruginous, and also very largely permeated by small veins of calcite which occur in such quantity as to make the rocks assume a strong resemblance to the nodular concretions of calcareous clay, so well-known as septaria, or cement stones, and largely used for the manufacture of hydraulic lime in England and other European countries. This point could easily be tested by a series of well-devised experiments, and if the

results be successful the existence of a very valuable economic material will have been demonstrated.

Clay bed N. E. and N. of Karjan.

Good looking grey clays are to be seen where the ground begins to rise above the river flat both to the N. E. and N. of Karjan, but seem to be absolutely unused, for no signs of quarrying are to be seen.

The Pardi-Dholan clay beds.

The great cliffy bank of the Tapti forming the eastern part of the Párdi Dholan section is composed of a thick bed of buffy clay of excellent colour, and very promising appearance, and, if of really good quality, offers an immense supply of material for use. At present this clay appears to be quite neglected.

6. *The Alluvial Formations.*

a. Fluviatile Alluvia. Not many of the formations met with in this recent geological group are of great economic value except as soils.

Tufaceous limestone or kankar.

The building materials they furnish are practically no stone, but only lime and sand and clay for bricks or mud buildings. The strata deposited by the existing rivers are except in a very few cases so little consolidated that they have but little coherence and cannot resist the crushing pressure which arises if heavy materials be laid on them. Even where lime has been deposited largely through them it very rarely binds the whole together, but is found segregated in nodules, or pipelike and ribbon shaped veins, which though of considerable intrinsic hardness themselves have not imparted sufficient general strength to the whole mass to unite it into a homogeneous rock. The strength of the semi-consolidated mass is so unequal even in closely adjacent parts that no trust can be placed upon its union. The segregation tufaceous limestone, commonly known as kankar, is of the most common occurrence at all levels in the alluvial beds, but is generally most largely developed near the base of the series. It is met with almost in every river or gully section to be seen in the country, and it is quite unnecessary to enumerate localities where it is procurable. It is constantly in process of formation and gives rise to islands in the rivers by cementing shingle banks sufficiently to resist ordinary floods and allow of the growth of tamarisk and other water-loving plants which form soil and assist

the warping action of subsequent floods by which the level of the islands is gradually raised.

The kankar is practically the general source whence is derived the whole supply of lime used in the country. Deposits of massive kankar that could be used as rude building stone were not seen of sufficient extent to be worth noting.

Sands. Great deposits of pure sand are not common. The most remarkable observed is one of considerable extent lying about half a mile N. E. of the railway station at Bahadurpur.

Pure sand is, however, very easily obtained from innumerable beds of unconsolidated or only half consolidated sandy clay by a very simple process of washing. This need only be resorted to in places at a distance from the large rivers and streams which yield an inexhaustible supply of sand good enough for all ordinary purposes. Such sand for example from the bed of the Watrak river at Mandwa, in the Atarsumba sub-taluq, is used in the manufacture of glass which is there carried on.

Brick earth. Brick earth of varying qualities is to be procured almost everywhere throughout the alluvial tracts, and is very largely used for making burnt bricks for the better class of buildings. Sun-dried bricks are also largely made for the construction of poorer houses and of walls for gardens near to towns and villages.

Soils. The economic value of soils is a question to be treated of more fully in articles on Land Revenue, but the distribution of the great varieties of soil is a point of great geological interest, and one which, had my time sufficed, I should certainly have gone into fully. It is greatly to be regretted that maps showing the areas occupied by the black, red, white and loamy sandy soils were not constructed during the progress of the Revenue Settlement, when all the necessary data for such maps were ready to hand, and they could have been constructed with great ease and at very small cost. They would have thrown much light on many agricultural and some ethnological questions.

Shingle and gravel beds. Shingle beds are important members of the alluvia of many of the larger rivers as the Sábarmati, the Watrak, the Mahi, the Orsang and Heran, in the two northern

Prants and the Kim, Tapti, Mindhola, Purna and Ambika in the Southern Prant, but despite their extent they offer nothing of value but road material and this is only really good where the shingle consists of hard and durable varieties of trap rock such as basalt, diorite, dolerite and andesite. A rich source of supply of such excellent material is to be found as I have pointed out further on (p. 137) in the Mahi river.

Rarity of good agates.

In but very rare cases do the shingle beds and gravels of the recent alluvia derived from the Deccan Trap contain agates or jaspers of sufficient size and beauty to be of value for lapidary's work. Even in reaches of the Tapti where agate geodes and fragments of jasper (of originally Vindhyan origin) occur by thousands, I saw none worth collecting. The generality were far too small to be of any use.

The Derda-Paori agates.

In only one instance did I come across good agates in the alluvium, and this was in the Majham river, a tributary of the Watrak at Derda Paori in Dehgam taluq. Here in the bed of the river just below a curious little ruined fort, attributed to one of the Mughal Emperors, is a bank of mostly coarse shingle, in which occur in some quantity well-rolled masses, varying in size from a man's fist to that of a small child's head, of agate or rather agate jasper, a rare variety of agate, but often of great beauty. The stones appear to have been true geodes, but show much less concentric structure than do ordinary agates, such for example as occur in the Rattanpur agate mines in Rajpiplas or in the rich agate shingle beds I discovered at Naroli Nahani in Velachha taluq and to the north of Galha in Kamrej taluq (see pp. 73 & 75). Of a small number of specimens, which alone I could bring away with me, several proved to be of considerable beauty, quite handsome enough to be well worth slicing and polishing.

Sandstones.

Beds of sandstone of some extent, but of no great thickness are of extremely common occurrence at the base of the alluvium in all the larger rivers which have cut themselves deep channels, but in the great majority of cases the rock is too little consolidated to be of real value, and it has in consequence been generally neglected, but I noticed several outcrops, *e.g.*, in the Sábarmati, N. of

Sadra and in the Watrak at Wagjipura and the Unch near Deroli where quarrying might be tried experimentally as the stone appeared to be fairly hard and suitable for rubble work.

b. Marine Alluvia.

These which are represented generally by sands and clays exposed on the coast and in the estuaries of the rivers falling into the Gulf of Cambay, show but very little of economic value. In only one case was such an application noted, and this was at Umrat in Nausari taluq close to the Maha Rajah's country house on the sea side between the estuaries of the Mindhola and the Purna. Here a brown ragstone full of marine shells of recent species has dug out from just below the surface and used for rough walls to some small extent. The stone is very fairly compact and strong. Very little of it is seen and its extent could not be determined. Its dark colour is very characteristic of the deposits forming under the Gulf of Cambay from the great quantity of dark trap sand carried down the Tapti and neighbouring rivers.

The Umrat shelly ragstone.

C. ROAD-MAKING MATERIALS.

The materials for making roads are in many places unfortunately entirely absent over great areas where they are really most urgently wanted, a stern fact which has been the cause of much difficulty and trouble to the inhabitants generally because the absence of roads practicable at all times of the year tends more than almost any other cause to retard the true advancement of the country. This unfortunate want of road material is most grievously felt in the taluqs which are entirely or mainly covered by the river and marine alluvia which, as will be seen by the maps accompanying this volume, lie on the western side of the State. Where the alluvial beds are covered by black soil, the mischief of having no roads is, as already pointed, infinitely greater, for in the monsoon the tracks speedily become impassable for wheel traffic and continue so till the country has had time to dry up again after the cessation of the rains. The red and sandy (loamy) soils are far less affected by the rains, and the regions they cover are in much better case.

Basaltic shingle in the Mahi river.

The necessary supply of road material could be procured from sources which do not appear to be appreciated at

present, for example in the case of the Mahi river immense supplies of trappean (mostly basaltic) gravel are to be got from the river banks and shingle beds lying no great distance from the railway bridge to which they could be conveyed by boats at very small cost. No finer road metal is known in the world than basalt broken up into good angular proper sized macadam. Baroda city could easily procure its requirements in road metal from this source. From here, too, could be taken the material to metal the roads branching off to the important towns to the westward of the railway.

The whole of Sauli taluq is within reach of the Mahi trap gravels on the west or of extensive spreads of basalt in the north-eastern part of the taluq.

In the Deo river and on Bairapur hill.

The western side of the Baroda taluq is within reach of the hard and dense basalts and andesites exposed in the Deo river and on Bairapur hill.

In Sankheda taluq.

Sankheda taluq is rich in road materials; the railway which crosses the granite tract at Bulwan could easily carry the stone, which would make good metal, though not quite equal to basalt and diorite, to Dabhoi and the huge black soil flat which lies between Baroda and the banks of the Nerbudda. The waste of the sandstone quarries at Songir, though rather soft for the purpose, could be used to make roads across the black soil flat which would be kingly compared with the state of the present tracks, whether in the wet or the dry season.

In Velachha and Kamrej taluqs.

All the laterite, limestone and sandstone outcrops in Velachha and Kamrej taluqs are handy to yield excellent material to metal much wanted railway feeders. The same can be said of the outcrops of laterite and trap in the Palsana, Moha and Gandevi taluqs, while further inland, when the trap country of Vyara and Songad taluqs is reached, fine road metal is to be had for the mere gathering and breaking it up into macadam. Even close to the coast at Umrat the recent shelly marine ragstone formation might be requisitioned to supply road material.

In Songad in Vyara, Namsari and Gandevi taluqs.

In the Northern taluqs.

To turn to the northern parts of the State in the Kari prant the supply of road material is less conveniently situated, but the country being occupied by a sandy loam or sand, the urgency for made roads is much less than in the

black soil tracts of the South. The laterite beds of the Sábarmati to the E. of Vijayapur and further up the river sand the hard granites of Virpur and of the hills to the N. E. of Kheralu would supply excellent and abundant material for feeding roads to the railway and to connect the many thriving and populous towns of that part. While once the roads are made, a trade in the fine building stones of the country E. of the Sábarmati would inevitably spring up and be of great assistance in building in a country which is so greatly deficient in timber. There is no need to enlarge on the other vast advantages which would accrue to the country generally by the provision of good roads passable at all times of the year.

D. Ceramic and Glass Making Materials.

If any modern pottery of high class quality is made in Baroda State, I certainly had not the good fortune to see any examples of it or to hear of its existence. The only pottery differing from common village workmanship that I came across was the polished and glazed ware manufactured at Patan, which though interesting, and some of it of quaint and grotesque shapes, does certainly not deserve to be reckoned of high class either as regards its beauty of shape or excellency of material or finish. At best it can only be called very third-class ware. It is very imperfectly fired and breaks readily in consequence. As is so often the case in India, the potter whose shop I visited had not got specimens of anything like all the forms that he could produce, so it was impossible to arrive at an even approximately complete idea of his craft capability. Excepting figures of animals and grotesque dolls, all the examples I saw were wheel made or moulded. The glaze was very badly applied to the figures or vessels treated to it, as in many cases large patches of unglazed surface remained and offended the eye greatly. The specimens of ware that I saw included bowls, plates, saucers, goglets, pipe bowls and water chambers, &c. Any clay of fair quality would be good enough to pottery of such a very middling class as the above.

The Patan pottery.

Mandwa's glass industry.

At Mandwa at the northern end of the Atarsumba subdivision of Dehgam taluq a small glass industry was being carried by the Thakur of the place, Perinayam Sahib,

a friendly courteous young Chief. The produce of the glasshouse consists mainly, if not entirely of women's bangles made of glass of poor quality and dull colours compounded by melting together "Oos" (reh) and quartz-sand and adding metallic colouring matter. The "oos" was collected in the neighbourhood, and the sand was the ordinary sand taken from the bed of the Watrak close by. Neither ingredients was at all pure in character, and the result necessarily a very poor "frit." The bangles turned out are equally of indifferent make, so it cannot be a source of surprise that the industry is moribund, as is the larger but equally poor one at the British town of Kapadwanj in Kaira taluq. The bangle trade is failing because a greater demand is arising for the better made and brighter coloured articles imported from Europe.

Bad selection of materials.

Glass of far better quality might be manufactured if the "oos" were refined and a pure sand used. Purer sand could easily be procured from the talus heaps around the various quartzite hills in Sankheda taluq and from other tracts occupied by quartzites of Champanir age in adjoining territories, as in Halol or Chota Udepur, or by substituting the pure white quartz found in the Vidwa Swamimata hill east of Sankheda town.

E. Decorative Stones.

Under this heading might be included the marbles, granites, porphyries, and breccias and other handsome stones already enumerated in the section on building stones, but there is no need to recapitulate the information already given above, so I will restrict this section to an account of the information I collected that might bear upon the establishment of a lapidary's industry to deal with the handsome agates and bloodstones to be procured in the great agate shingle formations at Naroli Nahani, and to the north of Galha in the Velachha and Kamrej taluqs respectively.

A small lapidary's shop conducted by some Cambay people was working in Baroda during the latter part of my stay there, but its outturn, as far as I saw it, was very poor and disappointing, and the prices asked for the things turned out, as compared with the prices charged for specimens such as are offered for sale by the lapidaries at Jabalpur, exorbitantly high.

Processes for cutting.

They either could not or would not make sections of large pebbles I wanted for the Museum, the reason being, as far as I could make out, that they could not slice them in European fashion, and to have cut them after their own fashion would have ruined very handsome specimens to no good purpose. The specimens I saw cut at the shop instead of being sliced in a lapidary's lathe had a surface produced on them by chipping, a process which simply wasted about half of any specimen so treated. They could thus only obtain one surface to be polished, while by the European system a large stone might be successfully cut into three or four or more slices, each offering at least one surface fit for polishing, while the specimen never yields less than two cut surfaces. The procedure adopted by these particular Cambay men was rude in the extreme, no better in fact than that followed by the neolithic people who preceded the iron age some thousands of years ago, for they did not get a stone into a state fit for polishing without wasting half or very nearly half of its bulk. Their system of chipping, which I saw applied to small objects only, *i.e.*, stones measuring not more than 3 to 5 square inches in surface, was to hold the stone against a light, rather blunt-pointed steel rod stuck up in a frame at an angle of nearly 65°, and to tap it sharply with a small long-handled hammer with a head made of a piece of horn. With this hammer they struck off small flakes rapidly and produced a rude plane with numerous conchoidal pittings, which was, as far as I could ascertain, then rubbed down with or without emery powder on a grit stone surface and finally polished by hand friction also. The polish produced was in no case that I saw a really high-class one; indeed, the whole process was characterized by clumsiness and inefficiency. Better result must, I should think, be secured by the lapidaries at Cambay itself, otherwise it is very remarkable how they should have made such a reputation as their craft and trade has acquired. Their trade lies mainly, I was informed with China, and consist very largely of beads and buttons which are mostly not articles needing high-class work. The material they use up is almost entirely derived from the agate mines at Rattanpur in Rajpipla State, 14 miles E. of Broach, which I visited in May 1894 to acquaint myself with the geology of the agate gravel beds there and the methods by which they are worked. I give a sketch of what I there saw, and some additional useful information about the mines, in the Appendix in Part III. of this volume.

PART II.

SKETCH OF THE GEOLOGY OF THE GAEKWARI DISTRICTS IN THE KATHIAWAR PENINSULA.

CHAPTER I.

GEOGRAPHY AND PHYSIOGRAPHY.

THE several Gaekwari districts in Kathiawar form together the Amreli Prant, or province, which is under the Suba of Amreli. There are six principal tracts each ranking as a taluq and a number of small outlying bits of territory known as "tapas."

Sub-division into six taluqs.

Five of the six taluqs are known as the Amreli Mahals; the most easterly of which is Shiynagar, followed westward by Damnagar and Amreli. South of the latter lies the Dhari Mahal, and south of it, but separated by a belt of Junagarh territory, lies Kodinar (Korinar) Mahal, which occupies the low level tract known as the "Nagher" extending southward to the sea. The sixth taluq is Okhamandal, which forms the extreme western extremity of the peninsula. Okhamandal used to be practically an island, being separated from the mainland by a "Rann" or flat covered by the sea at high tides, but of late years a high sandbar has been thrown up by surf action at the southern end of the "Rann" and has cut it off from the sea.

The relation borne by these six districts to the four great divisions of the Kathiawar peninsula of the olden time is the following: Shiynagar and Damnagar belong to Gohelvad, Amreli, Dhari and Korinar to Sorath and Okhamandal to Halar.

The aggregate area of the several tracts amounts to 1,320 square miles, the greater part of which is occupied by rolling plains which, as a rule, are very treeless and cheerless in their aspect.

Orology.

In the eastern and northern parts of the Damnagar and Amreli Taluqs the plains are diversified by a few scattered low ridges and small plateau topped hills which is the character also of the Okhamandal Taluq. The Dhari Taluq on the contrary is largely hilly, and includes great part of the well-known Gir forest, a tract zoologically interesting as being the last refuge of the Gujarat lion.[1]

To Gir Forest

The Baroda section of the Gir includes five groups of hills increasing in height from east to west and having a much greater and steeper descent to the south than to the north, which gives the range a far finer and bolder appearance as seen from the south.

The range extends for 31 miles E.S.E. to W.N.W. (within the Gaekwari territory) with a width varying from 15 to 10 miles[2] and is divided by different valleys into four hill groups which may be named, beginning from W. to E., the Sarkala, the Rojmal and the Chakrosar, the Nandivela, and the Lapala group, from the principal hills rising in them.

The Sarkala group.

The most westerly, the Sarkala group, contains the culminating point of the range, Sarkala Peak, which attains the height of 2,128 feet above sea level and forms, as seen from the south, a fine bold mountain ridge. To the west the ridge stops abruptly with a great fall, but to the east of the Shapnes pass the hills rise again to a considerable height in the Rojmal group, which extends eastward to the valley of the Rawal river (which drains southward into the Arabian Sea 12 miles west of Jaferabad). Rojmal hill (or Nilghai hill), the highest point in the southern part of this group, attains an elevation of 1,623 feet, but is a much less striking object in the landscape than Dundi Hill (1,584), 5 miles to the E. N. E., which forms a very beautiful sharp peak, the most striking object in the whole range when seen from the north.

The Rojmal group.

[1] This interesting feline race seems on the verge of extinction, although it is carefully protected by the game laws of the state of Junagarh, to which the southern and larger half of the forest belongs. At the time of my visit to the Gir only about 40 individuals, including cubs, were estimated to survive.

[2] These measurements are taken from the southern boundary of Baroda State northward and do not include the spurs of the range which extend southward into Junagarh territory.

The third hill group, which lies between the Rawal and its tributary the Bhimcha, attains its greatest height in the bold and striking Chakrosar peak, which rises to 1,450′ in height. The Chakrosar group.

The fourth group, which forms the south-eastern section of the range and lies between the Bhimcha and Malan rivers, contains no important hill with a special name within the Baroda territory, but in its southern part about 1½ miles inside the Junagarh territory rises the Nandivela hill, a broad dome-like mass which stand up high over the surrounding hills and is the highest point at the eastern end of the range, its height above sea level being 1,741 feet. A number of scattered low rocky ridges lie east of the Malan river, but do not deserve to be regarded as a separate group. The Nandivela group.

The fifth group of hills constituting the Gir range lies N.N.E. of the Nandivela group northward of the valley of the Dhantrawari river. Its culminating point is Lepala hill, a fine mass attaining a height of 1,547 feet. The Lepala group.

A small range of much lower hills (on the north side of which stands the large village of Jhar) runs across the northern edge of the Dhari Taluq for a distance of about nine miles in an E. by S. and W. by N. direction. Near its western end it is cut through by the Shetrunji river 2½ miles N. E. of Dhari. The river forms a short gorge, and at the southern or upper end falls about 50 feet over the edge of a hard trap flow. The fall, a very pretty one, is known as the Khodiar Mata fall and is held sacred locally. The highest and most westerly hill in this range is Dharitot peak, which measures 893 above sea level. The Jhar hills.

The extreme northern part of the Kodinar Taluq is hilly, but on a much smaller scale, few of the eminences rising above 400 feet above sea level, or a couple of hundred feet or so over the surrounding country. The few outlying hills scattered over the central and southern part of the taluq are all less than 200 feet high. Hills in Kodinar Mahal.

In Okhamandal, the highest elevation does not exceed 150 feet above sea level, and very few points attain to more than from 50 to 100 feet above the general surface of the country. The hills are mostly flat topped and form small Hills in Okhamandal.

plateaux in most cases more or less scarped round their tops.

Want of forests. Whether open or hilly, the country generally is mostly very bare of trees. Only in the southern parts of the so-called Gir forest is the country extensively wooded, but even here the trees are so stunted and miserable that the woodland hardly deserves the name of forest. This has been the effect of centuries of senseless mismanagement and neglect, of constant jungle fires and reckless hacking down of leafy branches to feed the goats which are kept in large numbers and do infinite harm to the forests by destroying nearly all the seedlings.

Hydrology of Amreli Mahal. The hydrological system of the Gaekwari tracts is very simple, the central part of the Amreli prant being drained by the Shatranji river, which rises in the highest part of the Gir.

Of Dhari Mahal. The south-eastern part of the Dhari Mahal, which includes the eastern end of the Gir, sheds its water southward into the Rawal and the Dhantrawari rivers and their tributaries, which flow southward into the Arabian Sea. The extreme south-west corner of the Dhari Mahal south of the Sarkala ridge is drained into the Hadak nullah, which further south changes its name into Singaora

Of Kodinar Mahal. and flows southward across the Kodinar Mahal, dividing it into two unequal lobes, of which the eastern one is nearly double the size of the western one.

A small corner of the Dhari Mahal immediately N. W. of the Sarkala peak is drained westward by an affluent of the Ojat river which joins the Bhadar, and so also is the small tapa of Bhalgam, a westerly outlier of the Dhari Mahal.

Of Damnagar Mahal. The centre of the Damnagar Mahal is drained by the Ranghola river, a tributary of the Kalubhar, which itself

Of the Northern Tapas. receives the surplus water of the northern part of the taluq and of the tapas of Chawar and Khijaria. The Southern tapas of Sakpur and Rupavati drain southward into the Shatranji.

The most north-easterly outliers of Baroda territory in Kathiawar; the small Mahal of Shihanagur and its tapas of Ratampur are drained by rivers falling into the Gulf

of Cambay, the two first named outliers by the Padalia and Keri River, the last named by the Ghela River.

The Coast Line of Kodinar Mahal.

Only two of the taluqs touch the sea coast, the Kodinar Mahal and the Dwarka Mahal, or Okhamandel peninsula. The nature of the coast line is varied in both cases. The coast line of Korinar (Kodinar) measures 15 miles in a straight line from the mouth of the Diu creek to the mouth of the Surmut River; the coast is mostly low and sandy, but in three places low hills of miliolite limestone occur and have been cut into cliffs of varying height.

Diu Head.

The first and most easterly of these hills is well known to sailors coasting between Bombay and Karachi as the Diu head, the southernmost point of Kathiawar, and is capped by a light-house. The hill rises 85 feet above sea-level and is scarped on its south side by cliffs from 60 to 70 feet high. To the N.E. of the hill is a small bight which it shelters from the blast of the S.W. monsoon, and in which a few coasting craft find shelter and a secure anchorage at that season. If a breakwater from $\frac{1}{2}$ to $\frac{3}{4}$ of a mile in length were thrown out N.E. ward from the eastern-most point of the headland, it would protect the bight from the swell raised by easterly and south-easterly winds and form a small but secure harbour, available all the year round, and of inestimable value on this otherwise harbour-less coast. The local name for the anchorage as it now exists is Velan Bandar or Marwar Bandar. Its potential value as a harbour and railway terminus will be more fully dealt with in Chapter VI. when treating of the economic geology of the Baroda tracts in Kathiawar.

Mul Dwarka.

The little miliolite hill, half a mile W. of the mouth of the Singaora crowned by a ruined temple and known as Mul Dwarka, is also scarped by surf action into a low cliff, on the south side of which a small but very typical sea cave has been excavated to a depth of some thirty feet, or thereabouts.

The Okhamandal "Rann."

On passing on to the Okhamandal country which was formerly an island, it is seen that it is now a peninsula connected with the mainland of Kathiawar only by a very narrow isthmus, which lies between the "rann" and the sea to the north of Madhi temple.

The "rann" has apparently no special local name, so it may for distinction be called the "Okhamandal Rann." It is really an arm of the Gulf of Cutch, the bed of which has been slightly raised, probably by some recent trifling upheaval of the land. The "rann" is nearly dry during the greater part of the year, but in the rainy season is covered with water. This is partly rain water, but partly also sea water piled up in the Gulf of Cutch by the wind pressure of the S.W. monsoon which blows for several months steadily with great force.

The isthmus is about a mile long by rather more than a furlong in width at its narrowest part. The western side of the isthmus is crowned by a ridge of blown sand, about 30 feet high, which hides the subrock, which where exposed further north and south is seen to be a limestone.

The shore consists of a shelving beach of thin sand resting on one or other of the limestone beds; the limestone is frequently exposed by the action of the waves, and its surface is then seen to be worn into grooves and small pot holes worn by the grinding action of the surf on lumps of coral thrown up from the fringing reefs. The coral lumps are worn into perfectly well-rounded pebbles of all sizes.

Dwarka cliffs.

From the southernmost extremity of Okhamandal up to Dwarka town, the shelving beach and blown sand ridge is continuous, but at the town the coast becomes cliffy and continues so for about a mile and a half up to the mouth of the Rupenbandar creek. The cliffs vary from 30 to 50 feet in height and consist of coarse shelly sandstones which form a small plateau.

About 3½ miles north of Rupenbandar creek the coast becomes cliffy again on a small scale for a distance of two miles at the most westerly projection of the coast.

Aramra Bay. Beyt harbour and Shankodar island.

As soon as the coast line begins to trend eastward, the low sandy character of the beach, backed by a blown sand ridge, is resumed and continues up to the most northerly point opposite Beyt island and all round Beyt harbour and eastward beyond it and right round into the mouth of the bay into which the "Rann" opens. Here the coast line is very broken and short lines of cliff occur at frequent intervals.

Coast line west and south of Positra.

This broken line of coast is due to the presence of small hills and plateaux which have been variously scarped by both subaërial denuding forces, and by surf action, prior to the elevation of the bed of the Rann above referred to. Though the islands and promontories along this eastern side of Okhamandal are quite on a small scale, few exceeding a hundred feet above sea level in their elevation, yet from their great diversity of shape and the bright orange, buff, yellow and brown colours of the beds composing them, they unite to form a most pleasing landscape and contrast strikingly with the extreme barrenness and ugliness of the greater part of the Okhamandal peninsula.

Beyt island shows several short lines of cliff on its western side aggregating to about three miles in length, and at the southern extremity and at intervals along the eastern side of the island the sea breaks along against low cliffs for short distances.

The rest of the coast is low and fringed with blown sand.

The sea margins of the "rann" and of several of the mud flats along the Positra promontory and the south and western sides of Beyt harbour show typical mangrove swamps.

Deleterious action of the west wind vegetation.

Along the whole western side of the Okhamandal peninsula the wind blows so strongly and carries so much salt spray that the growth of trees is almost entirely prevented except where they find shelter behind raised ground or buildings; elsewhere they present the most miserable grotesque apologies for trees I have seen in any country. Where shelter is provided for them they flourish well, and show that it is not the fault of the soil but solely the deleterious effect of the pitiless wind action. After seeing Okhamandal I can realize better than ever before the term "blasted" as applied to tree growth.

CHAPTER II.

THE SUCCESSION OF ROCKS AND PREVIOUS OBSERVERS.

THE succession of the geological formations met with in the Kathiawar Gaekwari is shown in ascending order in the following schedule :—

III. Recent	{	Alluvium and subaërial deposits. Miliolite.
II. Tertiary	{	Dwarka beds. Gaj beds.
I. Cretaceous		Deccan Trap Series.

Of these the Deccan Trap series occupies by far the largest area superficially, and is much the most important formation in every way, being in many parts of great thickness. It occupies the central plateau of the Peninsula, and excepting for a few small local patches of river alluvium forms the whole of the Damnagar, Amreli and Dhari Mahals, while a few inliers of it protrude over the surface of the miliolite in the Kodinar Mahal. It occupies also the Iswaria tapa of the Shiyanagar Mahal.

The Tertiary Gaj and Dwarka beds are met with only in the Okhamandal Mahal.

The Post Tertiary miliolite occurs only in the Kodinar Mahal, together with a small extent of alluvium close to the coast. The largest show of alluvium in the Baroda territory is in the Shiyanagar Mahal, the whole of which with the exception of the tapa of Iswaria (4 miles to the S.W.) lies within the great belt of coast alluvium which stretches from the Gulf of Cambay to the Rann of Cutch. The alluvium of the Okhamandal rann covers an area of some size (about 18 square miles) while the alluvial tract at Aramra at the northern end of the Dwarka Taluq is also too extensive to pass unnoticed.

PREVIOUS OBSERVERS.

Very little has been published about the geology of the Baroda Mahals of the Kathiawar Peninsula, practically

nothing beyond the very short memoir of Kathiawar by the late Mr. Francis Fedden, A.R.S.M., F.G.S., which appeared in 1884.[1]

His remarks on the several formations met with in Kathiawar have no direct reference to localities referred to in this memoir lying within the Gaekwari tracts except in case of the Okhamandal tertiary rocks and do not therefore require special notice. He appears to have devoted more time to the study of the rocks in other parts of the country, and justly so, for they offer many more points of geological interest than do those in the more central parts included in the Gaekwari territory; for this reason his memoir was very little use to me in working out the structure of the tracts I had to deal with. Mr. Fedden's Memoir mentions that parts of the south of the Kathiawar peninsula had been surveyed by Mr. Wm. Theobald, of the Geological Survey of India, and refers to his unpublished memoir on those tracts, but does not particularize clearly how the work was divided between himself and Mr. Theobald. It is only quite recently I have had access to the unpublished memoir in question and find it of no assistance to me whatever.

In the *Gazetteer of Kathiawar* only a very few incidental remarks on the geological features of the country are met with, and they similarly were of no special use in directing my attention to points of interest.

[1] The geology of the Kathiawar Peninsula in Guzerat by Francis Fedden, A.R.S.M., F.G.S., Geological Survey of India. Memoirs of the Geological Survey of India, Vol. XXI., Pt. 2.

CHAPTER III.

THE DECCAN TRAP SERIES.

Want of good sections.

In the area occupied by this great series of trappean rocks which it fell to me to examine, I came across no natural section of sufficient length and depth to throw much light on the sequence of the flows and their correlation. The matter of position and the very limited amount of time at my command did not allow of my making a sufficiently detailed survey of the country to map the horizons occupied by even the principal flows, though this could doubtlessly be done to a great degree of accuracy by any geologist having the necessary leisure. It would not, however, be a work of any great practical utility, though petrologically and chartographically very interesting.

Position of the trap flows.

The position of the trap flows in the north-eastern and northern parts of the Baroda trap area is, as a rule, one of horizontality, but in the hilly tract of the Gir and its spurs the flows have been gently tilted and show a low dip to the northward or north-eastward, probably averaging about 5°. This dipping is a very well marked feature in the landscape and shows distinctly on many of the bare hillsides, but it is not easy to find a flow surface that is sufficiently smooth to admit of measurement with a clinometer.

In the western better wooded part of the Gir forest the dips of the flows are less easy to trace and are not conspicuous from great distances as they are in the more treeless easterly hills.

As a rule with very few exceptions the tops of all the hills are composed of hard basaltic, or doleritic, flows which resist weather action far better than do the generally soft and highly vesicular amygdaloids, which are frequently seen on the flanks of the hills underlying the hard basaltic beds and frequently also form the bottoms of the valleys and the open plains. The general surface of the country is so largely covered with soils of various kinds that it is

impossible to say which variety of rocks prevails as to extent—the massive (basaltic) or the amygdaloid. No cases were noted of any trap rock weathering into black soil, as was assumed by earlier observers to happen frequently. The weathered trap rock is invariably of reddish or yellowish brown colour.

Absence of intertrappean formations, &c.

No intertrappean sedimentary formations of any kind, or beds of red bole, such as are common between the flows in the south-western parts of the trap area in the Deccan proper, were met with anywhere in Kathiawar, a circumstance adding much to the difficulty of determining the relative horizons of the different trap flows.

The trap area is traversed by many trap dykes intruded into the older flows. They are of all sizes and follow many different directions which are characteristic of two different groups of intrusions between which considerable petrological differences exist in some cases; but whether this differentiation holds good in all cases could only be determined by a closer and more special examination than could be made in the time at my disposal.

"Basic" and "Acidic" dykes.

Two great series of trap dykes must be recognized, and these are so clear and well marked that no difficulty exists in determining what dykes to refer to them severally. The larger and more numerous series consists of dykes of "basic" trap rock distinguishable by their dark and mostly black colour. The second series consists of dykes of "acidic" trap which are characterized by light colours and generally much less dense texture. In the latter series the percentage of silica, the acidic constituent of the rock, is materially higher than in the basic traps.

Relative age of the two dyke series.

Which series may be the older remains undetermined, as no good example of a distinct contact of dykes of the two series was met with. In the only case I came across of a contact, which will be described further on, the acidic dyke appears to cut the basic one and to have thrown the latter a distance of over 200 yards, and if this is really the case the acidic dyke was evidently erupted at a later period.

The dykes of the acidic series in several cases form much bigger and more important ridges than do any of the basic dykes in the Baroda areas.

The Acidic dyke series.

Only eleven dykes belonging to the acidic series were mapped in the Baroda tracts, though they occur very commonly and on a much larger scale in the Palitana and Bhavnagar tracts east of the Damnagar and Amreli Mahals.

The eleven above referred to are distributed as follows:—

In the Damnagar Taluq, 2, S. of Damnagar.
„ „ Sakhpur tapa of Damnagar 1.
„ „ Khakhbai tapa of Dhari Taluq 2.
„ „ Nigala tapa of Dhari Taluq 5.
„ „ Dhari Taluq (S.W. corner) at Dalkhania 1.

The Sakhpur dyke.

The most important and petrologically the most interesting of these dykes is the Sakhpur dyke which forms a rather big ridgy hill rising more than 300 feet above the surrounding plains, and running a distance of one and a half mile within the Baroda territory. To the north it dies down and is lost under the black soil plain, but to the south it extends fully another mile into the Junagarh State. The most prevalent variety of the acidic trap here met is a pale creamy to yellowish white mottled with brown and reddish brown and containing at intervals nests of chocolate-coloured dense clayey material.

The dyke which rises through a basaltic flow showing much spheroidal weathering is a very remarkable one and deserving of very close study petrologically, as it is made up of materials which seem to belong to two distinct irruptions and are extremely unlike each other in their facies. They may roughly be described the one as a mottled cream coloured brown and red ferruginous clayey trap, and the other as a gritty calcareo-siliceous rock chiefly pale whitish drab in colour, and both of them more or less amygdaloid in structure. In the first variety the amygdala are filled with gœthite forming the outer layer, while the centre is occupied by a confused mass of very small quartz crystals. The gœthite is a blackish brown in colour. In the second variety the cavities, which are very irregular in size, are partially filled with small crystals of quartz generally dull white, but occasionally purplish brown in colour. On these quartz crystals I found in three or four of the freshly broken amygdala some very minute shining prisms of very bright yellow green colour. To make sure

of their proper determination, I submitted these to Mr. L. Fletcher, F.R.S., the head of the Mineralogical Department of the British Museum, when at home in 1894, who thought them to be , but they were too minute in size and too few in number to admit of a sufficient analysis, such as they deserved because of their great interest.

Both varieties of rock are unlike any trap I have come across anywhere, or read of as occurring elsewhere. The darker ferruginous mottled amygdaloid appears to have been the first intrusion into the fissure and to have been followed at a later period by the intrusion along the eastern side of the fissure of the pale calcareo-siliceous magma which forms a much narrower band. This opinion I advance with some reserve, as the section is not a clear and well defined one, and no quarries have cut into the greatly weather beaten surface of the great dyke.

Dykes south of Damnagar.

Two dykes of acidic trap bearing considerable likeness to the Sakhpur rock lie to the southward of the little town of Damnagar. The rock composing the more northerly of the two, which has a course from N. W. by N. to S. E. by S., is an argillo-calcareo-ferruginous amygdaloid ranging from white through yellow and reddish brown to dark brown in colour with a texture varying from rough to nearly jaspideous. The rock has been largely quarried and exposed to a depth of as much as 30 feet in places—so its appearance cannot be due simply to superficial weathering. The dyke is altogether a mile long and stands up well from the surrounding country. The rock through an amygdaloid is dense enough to furnish building stone of fairly good quality. The more southerly dyke, a much smaller one which forms the crest of a knoll jutting out northward into the Damnagar valley, lies a quarter of a mile N. of Pandarsinga, and has been considerably quarried and yielded a material very similar to the Damnagar dyke just described.

In all these dykes portions of the rock here and there have a decidedly trachytic facies, but that is certainly not the general character of these dykes, which is quite sui generis and unlike any volcanic rock that I am acquainted with personally. The occasional trachytic facies suggests the question whether the general mass of the rock may not

have been originally trachytic and have been altered by hydro-thermal action on a large scale. Numerous irregular bandings and veinings of cherty nature which permeate the rock in parts of the Sakhpur dyke especially are in some measure indicative of such hydro-thermal action.

Nigala and Kakhbhai dykes.

The great acidic dykes occurring in and immediately west of the *tapa* of Nigala are petrologically very nearly identical with the Damnagar and Sakhpur dykes, and so also are the dykes of the Kakhbhai *tapa*.

Dhalkania dykes.

Another remarkable occurrence of acidic trap is the great dyke on which stand the ruins of the little "burj" or fort of Dhalkania in the S. W. corner of the Dhari Taluq. The dyke which forms several low hilly and rocky ridges may be followed from S. W. to N. E. for a distance of 8 miles. The south-western end runs up to the top of the 1316′ trigonometrical station, one of the north-eastern spurs of the Sarkala group in the Gir range, and the north-eastern end is seen in the 923′ station 5 miles S.W. by S. of Dhari town. At the north-eastern end the dyke rock is quite of the Sakhpur type, but in the central part of the course to the N. E. of Dhalkania village the rock assumes great similarity to serpentine. Further south-west again, however, at Dhalkania village and Kotra the Sakhpur type of amygdaloid reappears.

The basic series dyke.

The basic dykes were met with in large numbers and some of great length and considerable thickness, and many of them form the crests of ridges many miles in length and high enough to form striking features in the landscape. In the southern hilly part of the Dhari Mahal they are very numerous, but in the northern parts, *i.e.*, the Amreli, Damnagar and Shiyanagar Mahals they are not common.

An enumeration of them is not very easy, for it is often difficult to decide whether certain trap ridges shall be reckoned as distinct dykes, or as extensions only of adjoining dykes of similar petrographic character and with similar direction of course.

In the Dhari Mahal and its outlying tapas of Kakhbhai and Nigala on the east and Bhalgám and Bháder to the west, counting only such dykes as have a distinctly different

strike, and are of different varieties of trap, the number comes to over 200 (say 208), while in the Amreli Mahal there are only 10, in Damnagar Mahal only 9, and in Shiyanagar Mahal only one large enough to be mapped. If each separate outcrop were reckoned as a distinct dyke, the total number would be doubled if not tripled. The dykes shown on the printed map are only the more important ones; to have attempted to show all would have crowded the map unduly and have spoilt the general effect.

The only two parts of the world that I am acquainted with where equally great shows of dykes are to be seen are, firstly, a tract of country lying in South-Eastern Gujarat and including the Rajpipla hills and the extreme north-western spurs of the Sahyadri range (between lat. 22° and lat. 22° 30′ north) where the Deccan Trap flows are closely seamed by great numbers of prominent basaltic or dioritic dykes of upper cretaceous age;—and secondly, a tract including the northern half of North Arcot District and the southern half of Kadapa District (in the Madras Presidency), and lying roughly speaking between lat. 14° 20′ and lat. 12° 20′ north where the granites and gneisses of the Archæan system are cut up by vast numbers of dioritic and basaltic dykes, many of them of great size and length and disposed, as it were, in a great network on a yet larger scale than in Gujarat and Kathiawar.

The dykes in this latter tract are of vastly greater antiquity, geologically speaking, as none of them were intruded subsequently to the opening of the Kadapa age, and many of them had been formed before the commencement of the Dharwar age, the rocks of that system resting unconformably on the denuded crests of the dykes. The great majority of the dykes are dioritic or basaltic. But in all three cases the extraordinary network of intruded veins shows the great extent to which the earth's crust had been fissured locally by the subterranean pressure of the great mass of molten rock struggling to escape to the surface.

The following notes refer to a few of the more interesting of the basic dykes which are worth special attention,—the great majority of them not presenting any

features of practical value, or exceptional scientific interest sufficient to demand individual notice :—

Dykes in the Damnagar Mahal.

A large and important dyke forms the crests of a line of small hills which runs E. by N. to W. by S. on the

The Dhrupnia dyke.

north side of the Dhrupnia valley 3½ miles N. E. of Damnagar. The rock is an intensely black tachylitic trap, almost vitreous in texture. A mile and a quarter W. of Dhrupnia it changes its course and trends north-westwards for a couple of miles and then trends again to W. 5°s. Its course within the Gaekwari territory is just upon six miles in length.

Karkolia dykes.

Two low but well-marked rocky ridges, each about a mile long, rise from the plain, the one immediately E. of Karkolia village, the other 7 furlongs to the south. The former is an ordinary Diorite, the latter a very dark, almost black, diabase. These rise through a basaltic plateau which occupies the southern half of the Chávad "*tapa*." The basaltic plateau ends northward at Chávad in a bold scarp about 100 feet high, at foot of which commences a broad spread of amygdaloid which occupies the northern half of the tapa and extends up to and beyond the Khalubhai river. A number of small outliers of basalt remain capping the amygdaloid plain.

The Ambaldi dyke.

To the west of Ambaldi, the most northerly village of the Damnagar Mahal, is a noteworthy dyke of very fine grained basalt which forms a low ridge extending for nearly 6 miles N. N. W. up to the Khalabhai river which it crosses and thus extends beyond the Baroda territory.

Dykes in the Amreli Mahal.

The Versara dyke.

In the Amreli Mahal there are but very few dykes worth noting; the first to be named is a large dyke lying north of the village of Versara in the N. E. corner of the Mahal, and forming a low ridge cresting the top of the local downs. The rock is a very dense black basalt, which is comminuted to a remarkable degree by three principal series of joint planes; of these one is parallel to the course of the dyke (E.N.E.-W.S.W.), the second cuts it at right angles, and the third is practically horizontal. Their joint effect has cut up the dyke into a ready-made store of splendid road metal. The dyke extends for a distance over 3 miles.

The Kátma dyke.

A large and conspicuous dyke forming a well-marked rocky ridge of large blocks of Diorite runs W. S. W. to E. N. E. for a distance of 4 miles past the village of Kátma close to the N. W. corner of the Amreli Mahal. It extends at both ends far beyond the Gaekwari, its total length being over 17 miles.

The Akkádia Mota dyke.

Not quite two miles to the southward of the Kátma dyke and parallel with it are two outcrops of another dyke of similar diorite occurring in large blocks. The outcrops are nearly 2 miles distant from each other, but there can be little doubt that they are parts of one and the same dyke.

The Jhália dyke.

Another outcrop of large-blocked diorite of similar character, and running in the same direction, occurs to the westward of Jhália 6 miles S. S. W. of Akkadia Mota village.

Gaodka dyke.

The only other important dyke in the Amreli Mahal occurs at Gaodka on the north side of the Shatranji river. The rock here is a basalt occurring in large blocks which have been extensively quarried. At a distance of two miles to the W. is another outcrop of the same dyke, and a second extension of it is to be seen nearly a mile further west in the valley of the Sitali river.

Dykes in Dhári Mahal.

In the Dhári Mahal as already mentioned, and as very clearly shown on the map, the number of dykes is very great, and the very great majority of them are basaltic, and except in size and direction they differ very little from each other and offer but few points of interest on megascopic examination. They offer doubtless an interesting field for close petrographic and microscopic study, but this could not be attempted in the very rapid traverse that I was compelled to make in the very limited time at my command.

As shown in the map there are many crossings and intersections of great dykes, as for example to the south of Jira at the northern end of the valley of the Rával river, but in no case did these assemblages of dykes form a true radiant plexus such as is supposed by some geologists to indicate a former volcanic cone.

In no case in which the bearings of a dyke were taken was the compass needle at all affected, indeed no magnetic influence was observed to be exercised by any rock examined by me in Kathiawar.

No trappean dykes.

Beside the basic and acidic dykes above described, three other kinds of veins or dykes are met with traversing the Deccan Traps, namely (1) dykes of calcite, (2) of variolitic chert, (3) of variegated jaspery chert which are ranked in the order of their real importance.

Calcite veins.

These remarkable veins seem to be restricted to the Trappean area of Kathiawar only. None were seen by me in the Deccan Trap of Gujarat, or of the South Mahratta country, and no mention of similar veins elsewhere is to be found in the Manual of the Geology of India, nor in any descriptions of trappean areas in other countries that I have referred to. The veins appear as ordinary dyke-like ridges rising from a few inches to 30 or 40 feet above the general surface of the country. They are most probably veins of segregation formed by hydrothermal action and not veins charged by injection from some great subterranean cavity full of a volcanic magma. The white siliceous sinter which is so largely associated with some of the calcite veins bears a strong resemblance to hot spring deposits.

Excepting quartz crystals, no accessory minerals were observed in connection with the calcite veins which are not very numerous, but are striking features where they attain to any size. All occurring in the Gaekwari with two exceptions lie within the limits of the Dhari Mahal and in its eastern half. Counting large and small, 17 veins in all were seen and mapped.

Daragni veins.

Taking them from north to south and starting from Daragni on the western bank of the Shel river, the first calcite veins met with are a group of three, a mile from Daragni. These run nearly due east and west, and their western extremities pass under the black soil plain in the small state of Lakhpadar—their eastern extremities being similarly lost under the black soil which shrouds the general surface of the country. They are best seen in the small

nulla W. of the road to Samadhiala; the largest of the three veins is quite 10 foot thick.

The largest and most interesting of the calcite veins are the twin veins at Jikiali and Kotada which run roughly parallel for several miles, allowing for many breaks in the continuity, especially of the northern vein. Their course is E. N. E. and their entire length 9½ miles from their western end near Gadhia to the point where they leave the Gaekwari and enter Bhaunagar State. The Jikali and Kotada veins.

The southern vein is on the whole much the more important, and forms well marked ridges 40′ to 50′ high at Jikiali and Kotada villages. At the latter village the vein is cut across by the Shel river, but the section is an unsatisfactory one, and does not show clearly the relation of the calcite to the trap rock it traverses. The vein stone is here a singular mixture of dead white calcite and white siliceous sinter, which latter greatly resembles a very close-grained whitish limestone. The deception vanishes, however, the instant the hardness of the rock is tested. The sinter is extremely hard and tough and forms the principal part of the vein locally. All the sinter seen *in situ* was white, or greyish, in colour, but many bits of a handsome red and a few of green colour were found scattered to the eastward of Kotada. The more westerly extensions of the twin veins form two well-marked ridges immediately N. of Ingorala, and then after a break a mile long reappear on the high ridge on which stands the 1133′ Trig. station. They finally disappear a mile eastward of Gadhia.

A branch vein with a S. W. by W. course branches off from the western end of the 1133′ ridge, and runs for more than ½ a mile before dying out. The veins are generally more cherty than calcareous, but in contact with the calcite much opaque white rock crystal has formed, and where exposed to weather action the spaces between the crystal pyramids are partly filled with a stalagmitic encrustation which present an appearance of having been formed by a process of drifting. One very fine specimen of this is in the Baroda Museum collection, No. 323.

Only one other calcite vein is deserving of special mention, and this is a very moderate sized one which occurs Pipalwa "Marble" vein.

east of Pipalwa and 4 miles S. of Lapala hill. It is specially interesting despite its small size because it is much less siliceous than any of the others, and then shows two bands of moderately crystalline calcite from 2′ to 3′ thick dipping nearly vertically. In colour the mass is speckled buffy white and grey, and is capable of being cut and polished into a handsome marble.

Other veins. Of the other small veins, three occur S. of Jikiali at Vankia, and two south of Kotada, one at Hirava and two at Jira, more nearly in the centre of the Mahal.

Mandaváda veins. The two exceptions above referred to as not occurring in Dhári Mahal are two very small veins N. of Mandaváda on the western edge of Amreli Mahal.

Variolitic Chert.—Four veins of this often handsome stone were met with in the Dhári Mahal, but no direct connection could be traced between them and the veins of sintery calcite or of coloured chert just described. In only one case was a variolitic vein seen close to a calcite vein.

Kotada veins. This was at Kotada just where the calcite ridge dies down a little to the east of the village. Here the yellow variolitic vein cuts the calcite vein at right angles, but no actual contact of the rocks is seen.

The next variolitic chert vein met with lies two miles to the south of Kotada. The chert here is of rich deep yellow colour, and forms a small cross course cutting a small trap dyke nearly at right angles. It is unconnected with any calcite vein. Its course is N. N. W.—S. S. E.

Dalkhánia vein. The third and largest of the veins occurs 1½ miles to the E. S. E. of Dalkhánia. It lies parallel to a large trap dyke on its northern side close to the track leading to Sakhpur. The vein is exposed for several hundred yards in length with a probable thickness of from 6 to 8 feet. The chert is of rich colour in shades of yellow, orange, red and reddish brown, and is typically variolitic in texture.

Shemardi vein. The last of the four veins is to be seen at Shemardi rather more than two miles to the south of Dalkhánia village. The stone is yellow in colour, and has mixed with it a little trace of calcite.

Many subangular pebbles of this variolitic chert are to be seen in the gravels of the Shatranji river, especially a little above the fine camping ground at Bábapur. The

stone had attracted the notice of the old neolithic workmen, and many worked flakes of it occur in the same gravels.

Jaspery Chert Veins.—Small veins of bright-coloured jaspery chert occur in a few localities in the eastern part of Dhári Mahal, *e.g.*, at Khamba on the Dantravári river, and to the south of Nigala in the outlying tapa of that name. Other veins doubtless occur here and there, otherwise it is difficult to understand the wide distribution of *angular* fragments of such chert over the country, unless indeed the frequent presence of the chert fragments be attributed to human agency, for which there is some ground, as the old people of the neolithic and early iron ages were very fond of using the coloured cherts for the manufacture of flakes, as proved by the finding of a few of the latter and of very numerous cores in many places in the Gaekwari. These veins, which are evidently segregation veins, are very ill-defined, for exposure to atmospheric influences very soon comminutes the mass of the veins as they may become exposed.

The prevalent colours of these cherts are shades of red and pink, purple, green, blue, yellow, brown, and grey.

The Khamba vein.

The vein at Khamba, which is the best defined, is perhaps three feet across and exposed for a distance of 50 or 60 yards, but it probably extends much further under the soil of the field to the south, as the surface is plentifully strewn with chert fragments. The largest mass seen was equal in size to about half a cubic yard, but was not solid throughout, parts of it being rather cellular, possibly from the weathering out of some less durable mineral. The vein has a N. by E. to S. by W. course.

The Nigala vein.

The Nigala vein was even much less definite, and could only be said to be indicated by the distribution of fallen blocks on the east side of the bassett edge of a dioritic flow near the centre of the southern half of the tapa. I could not satisfy myself as to any of the blocks of chert being still *in situ*.

At neither of these two veins were there any signs of the chert having been collected as an economic product in recent times, though the very handsome colours of much of the stone would lead one to expect that some notice must have been taken of such a brightly tinted rock by modern lapidaries.

CHAPTER IV.

TERTIARY FORMATIONS: GAJ AND DWARKA BEDS.

THE area occupied by these sedimentary rocks in the Baroda State is very limited and they occur only in the Okhamandal Mahál.

Gaj Beds.

The Gaj beds, which are the older of the two series, are seen only on the eastern side of the Okhamandal peninsula and in three separate patches: (1) The low tract lying east of Lowaráli and Dhenki and stretching for 8 miles N. by E.—S. by W. along the Rann between Meripur and Tupni. (2) A narrow and very sinuous strip at base of the coast scarp from the headland N. E. of Tupni to that opposite to Dabdaba island. (3) A rather shallow basin of roughly oval shape separated from the coast strip by a narrow band of overlying Dwarka beds. This basin which may be called the Katumba basin, after the only village standing within its limits, measures a little over 6 miles in length from N. to S. and rather more than 4 from E. W. in its extreme width. Its extent and shape are very well represented by the contour lines shown in the 1″ Topographical map. The principal rocks of the Gaj series seen in these three exposures are marls, clay marls and sandy clays. The marls are in some cases of bright reddish buffy to nearly red in colour, in others they are pale yellowish or drab, as are also the majority of the clayey beds.

Fossils in the Gaj Beds.

I came across no fossils in these beds, but Mr. Fedden, who had more time to devote to hunting for them found, "a remarkably large variety of *Ostrea multicostata* in soft arenaceous clays exposed in the bank of a creek-like recess east of Lowaráli; and tubes of *Kuphus rectus* in the soft clay marl of the scarp above the bank." "At the same locality (Lowaráli) in Okhamandal with *Grammechinus regularis*, Duncan and Sladen, were found *Pecten Soomrowensis*, C. Sow., *P. favrei*, d'Arch., *P.* (*Vola*) *sub-corneus*, d'Arch. and Haime and casts of spirals."

These Gaj beds are of Miocene age, and the fossils they yielded in Kathiawar were examined, described and figured by Professor P. Martin Duncan, F.R.S., and Mr. W. Percy Sladen in Vol. I. of Series XIV. of the Palæontologia Indica.

Dwarka Beds.

Overlying the Gaj beds are a series of marine sedimentary rocks of undetermined geological age which Mr. Fedden separated from the former because of the marked change in appearance and mineral character they present and the absence in them of any Gaj fossils. They contain very few recognizable fossils, though many of the calcareous beds are very largely made up of comminuted sea shells. In the southern part of Okhamandal the low-lying plains and valleys are occupied by yellowish to reddish yellow soft clays, or earthy marls, overlaid by coarse ill-consolidated gritty limestones which often form thick flaggy beds—they are generally of drab, greyish-white or buffy-drab colours—pinkish white beds are uncommon and so are brown ones. The limestones are scattered about all over Okhamandal in the shape of small plateaus of circum-denudation, many of which have been weathered into most irregular shapes, but on the whole they show a tendency to meridional extension, as is well seen in the plateaux to the E. and N. E. of Dwarka, *e.g.*, those of Wasai, Dhrásanvel, Kalianpur and Gadechi, and very markedly in those E. and N. E. of Katumba and Mulvel.

Several very sharp-cut small plateaux of this limestone occur rising out of the low-lying tract (No. 1) east of Lowaráli and out of the Katumba basin (No. 3).

Brecciated Limestones of Rajpura Bandar.

Very different in appearance from the prevailing type of flaggy limestone forming the various small plateaux alluded to above is the hard, close-grained, grey-mottled brecciated limestone which forms the rocky hillocks standing up close to the beach at Rajpura Bandar opposite to the south end of Beyt island, or Shankolía Point. The limestone which is obscurely bedded has been much contorted, to which doubtless much of its brecciation is due. No fossils were seen in it by me. A more extensive, but rather lower, group of similar rocks forms the back-bone of Keu island. The Rajpura Bandar hillock rises 71′ above sea level.

Of identical character is the limestone forming a group of four rocky hillocks which lie from 1 to 1½ mile N. W. of

Rajpura. No connection between this peculiar limestone and the other Dwárka limestone beds can be traced owing to extensive deposits of soil surrounding the base of the hillocks, but its facies is that of a palaozoic, or even older rock, and this suggests the idea of its being a remnant of some very old geological formation which had been left standing by itself, and which had had the much younger Dwarka beds deposited around its base. This is of course a mere speculation which cannot be proved or disproved, except by the finding of test fossils, or of some section which would explain the relationship of these very dissimilar rocks.

Beyt Island.

Beyt island consists of marls with sandstones and shelly calcareous sandstones sufficiently consolidated to be useable as rough building stones.

In one of the buffy marl beds on the south coast of the island just S. of the Nilkant temple occur many black moss-like and fucoid dendritic concretions of oxide of manganese, which add greatly to the hardness of the rock and cause it to assume a very rough surface when worn by weather or surf actions. The northern half of the island is very low and much covered with flown sand.

Gypsiferous clays of Kuranga.

To return to the southern extremity of the Okhamandal peninsula—the yellow sandy clays between the Kuranga plateau and the Khára Khetar salt-lake valley contain many crystals, large and small, of a very pure selenite (sulphate of lime). Many groups of crystals are large enough to weigh several pounds.

Bárdia Limestone.

Five miles S. E. of Dwárka town, a small valley, lying to the south of the village of Bárdia, runs S. W. down to the sea, and at its lower end, a couple of hundred yards from the beach, the stream draining the valley exposes a bed of compact pinkish-yellowish limestone largely composed of comminuted sea shells, which appears to lie near the base of the Dwárka series. The rock, which is a very pretty looking one, did not contain any recognizable fossils.* A

* This bed of limestone is also exposed on the beach as a narrow belt skirting the line of blown sands which extends unbroken, except by occasional stream estuaries, all along the coast. Many small potholes and irregular channels are being worn in it by the grinding action of the surf operating on lumps of coral thrown up during storms, &c. The coral lumps are worn into typical well-rounded pebbles.

red rather marly shell limestone was noted at the abandoned village of Morana.

The Dwárka headland is formed by a small plateau of coarse shelly calcareous sandstone, which forms to seaward a line of cliff extending from a little north of the mouth of the Gomti up to the mouth of the Rupen Bandar creek, a distance of about 1¼ mile. A very heavy surf breaks against this line of cliffs (which are from 30 to 50′ high) during westerly winds which prevail for at least seven months in the year, but the inroads of the sea are much retarded by the breaking down in great blocks of the upper and harder bed of the sandstones which form a regular and very efficient breakwater and protect the softer underlying bed for long periods. The Dwárka shelly sandstones.

A similar but lower line of cliffs extends for about two miles along the coast to the N. and W. of Kachigadh.

CHAPTER V.

POST TERTIARY FORMATIONS: 1. THE MILIOLITE: 2. THE ALLUVIAL DEPOSITS: 3. THE SUBÆRIAL DEPOSITS.

1. *The Miliolite Formation.*—Miliolite is a finely oolitic freestone composed in great part of foraminifera[1] whose tests form the nuclei of the oolitic grains of which this marine limestone is made up. Very nearly the whole surface of the Kodinar Mahál is occupied by this valuable stone from which the State may, by judicious encouragement of trade and enterprise, realize a very handsome income as I hope to show in the chapter on Economic Geology.

In the northern part of the Mahál the miliolite is seen resting unconformably on the surface of the Deccan trap series and lapping round the protuberances many of which rise over the northern part of the Naghêr, as the coastal plain is called. Some of the higher protuberances were probably islands in the miliolite sea, but the lower ones have been exposed by the denudation of the upper beds of the miliolite series. Except where the trap exposures have a blocky surface they do not contrast very greatly with the miliolite because the latter though white or pale cream coloured when freshly exposed acquires from weather action a dark leaden or dull grey colour. The Naghér plain is generally fairly level, but here and there low hills remain, *e.g.*, at

Miliolite hills.

[1] Miliolite was the name proposed by the late Dr. H. J. Carter, F.R.S., and since adopted by Indian Geologists generally. He described it as follows:—"In 1848 I examined portions of it both microscopically and chemically, and found it to be composed of minute foraminiferous shells and a few grains of quartz and hornblende: the former semi-consolidating the whole mass by a partial solution and recrystallization of their surfaces: and when dissolved in acid yielding yellow ochre casts of the foraminiferous animals they formerly contained. It thus became evident that the so-called Porebunder stone was the marine type of a formation which from the presence of gritty particles of foreign matter might contain impurities of this kind to such a degree that in some parts it might be a coarse conglomerate, while in others it might be wholly calcareous."

Harmaria, Alídar and Dolása near the eastern boundary of the Mahal and between Kodinar and Arnej along the western boundary. Along the coast are four eminences: the little hill on which the old ruined temple of Mul Dwárka stands, and further to the east a few low hills of sandy miliolite mixed up with blown sand dunes at Chará and to the west of Velan. Lastly, there is the cliffy hill south of Velan, crowned by a light-house and forming a conspicuous land-mark known to navigators as the Diu head, the extreme southerly point of the Kathiawar peninsula. It rises 85 feet above sea level.

Thickness of the formation.

The miliolite series attains a thickness of about 100 feet, and the beds though often very homogeneous show much "false" or diagonal bedding in many sections. The scenery as a rule is tame, and the hilly parts are mostly barren-looking, having been stripped of all trees and large bushes; in many parts also the rock surfaces are too continuous to be able to support any but the most stunted vegetation.

Coralloid weathering of the surface.

Some of the bare limestone surfaces show a singular form of coralloid and spongiform weathering, the surface showing circular holes a few inches deep inside a low cone as if they were remains of large cup corals. On some few square yards of surface at the northern end of the rise W.N.W. of Arnej so many of these circular pits occur close together as to remind one forcibly of a map of the moon showing many lunar craters. The appearance of coralloid structure is purely superficial, and no trace of it is seen on breaking up the rock. This peculiar form of surface weathering is very largely developed on the low hills around Wadnagar to the north of Kodinar town, and gives the rocks a very singular appearance.

Sections.

The two most interesting natural sections of the miliolite I came across are both in the bed of the Singaora river, the first just south of where the river enters the Baroda territory, the second immediately east of the large village of Ghántwar a couple of miles further down the river.

The Sakpur section.

The first section, which lies just north of the ruins of the abandoned hamlet of Sakpur, is a rather deep cutting in the miliolite which has been cut right through and the

underlying trap, a very large celled greenish amygdaloid,[1] exposed. The section has formed a roughly triangular pool with cliff of miliolite from 20 to 60 feet surrounding it. At the northern end the river falls over the edge of a terrace about 20 feet high. The cutting back of the river channel has been in progress for a considerable time and must proceed with great energy during the rainy season, to judge by the great size of some of the pot-holes excavated. The work of erosion must have been greatly assisted by debacles during great floods by which huge masses of rock have been torn off the cliffs and some of the old pot-holes split in half,—the remaining halves showing now as caves at the base of the new cliff face. The whole section forms a very lovely spot with plenty of flowing water and rich vegetation, a place in which every lover of natural scenery would love to linger. For a thickness of 2 feet at the base the miliolite is coarsely conglomeratic and contains many large trap pebbles.

The Ghántwar section.

The second of the two sections is a shallow cañon in the miliolite not more than from 20 to 30 feet deep, but penetrating nevertheless down to the underlying trap. The miliolite may be conveniently studied in the vertical scarps of the cañon which is just about a mile long.

The cañon character of the rock-cut river channel continues for 4 miles further down the Singaora as far as Cháchar, but below that the channel widens out and assumes the ordinary character of an Indian river. The cañon is specially well marked immediately to the N. of Cháchar, where it is from 40 to 50 feet deep with vertical sides. Many huge blocks remain in the bed of the river where they can only be moved by debacles during heavy floods.

[1] The very largest amygdaloid I ever saw was exposed in a dry part of the river bed. The upper part of it had been recently removed by flood action, but the lower part remained adhering to the trap surface. This huge geode measured fully 2 feet in length, by 16 or 17 inches in width, and when unbroken was probably quite 10 inches thick. It showed a large irregular cavity with beautiful slender prisms of limpid quartz (rock crystal). Like most of the large flattish geodes it was broken up by so many cracks that it was impossible to extract it entire, but many handsome pieces of it were collected for exhibition in the Baroda Museum. The good condition of the prisms showed that the upper half of the geode could only have been removed a short time previous to my finding it.

The only non-miliolitic sedimentary deposit met with in association with the true miliolite is a compact brown limestone with a gritty-looking texture which covers an area of several acres in extent to the N. E. of Shedaya on the track to Aritia. The beds roll about at low angles, but there was no section to show the thickness of the formation nor its relation to the surrounding miliolite spreads. It probably represents aninlier of some older rock showing up through the miliolite, its relations to which are completely masked by the general spread of black soil. The brown limestone at Shedaya.

Not the faintest indication of any organic remains could be seen in the limestone.

2. *Alluvial Deposits.*—Formations of this age and class occupy but a limited space in the Kathiawar Gaekwari. The only parts where they affect the character of the country appreciably are in the extreme eastern part in the Shihanagar Mahal, more than three-fourths of which lie in the coastal belt of alluvium formed by the rivers draining into the north-western corner of the Gulf of Cambay. The greatest part of the Mahal which forms the tapa of Ratanpur and is traversed by the Keri river is a low dead flat, the most uninteresting and most unrewarding kind of country that a geologist could waste his time over. That it is both fiscally and historically equally uninteresting may be safely inferred from the brevity of the notice of it given in the *Kathiawar Gazetteer*. It is there dismissed with a paragraph eight lines in length only.

The little edgings of alluvium accompanying the rivers in the Damnagar Mahal deserve no notice, and in the Amreli Mahal, the only alluvial tract worthy of mention, is that lying along the E. to W. valley of the Shatranji and Sitali rivers which is joined near Lonaria to the alluvium accumulated by the various streams draining the north-eastern part of the Dhari Taluq. The alluvium where exposed in the open plain is mostly sandy; generally, however, the general surface is so masked with black soil that it is quite impossible to draw any boundary line between the true alluvium and the underlying Deccan trap. Further south the alluvium, which is exposed by very many well sections in the rich plain lying between Chalála and the foot of the Jhár hills, shows a great alteration in character, from sandy Alluvium of the Shatranji.

or even silty it changes to coarse gravelly sands containing as the hills are approached many small boulders, which prove that at the time of their deposition the streams draining the northern edge of the terrace formed by the Dhari Taluq had a markedly torrential character and carried along large quantities of coarse imperfectly rounded detritus. Subsequently to the deposition of this coarse gravel great quantities of tufaceous calcareous matter derived from the decomposition of the trap flows forming the Dhari terrace were infiltrated and formed a tufaceous matrix binding the whole into a coarse concrete.

The Fatel Bara creek.

The alluvial deposits in the Kodinar Mahal are very unimportant, and only those in the S.E. corner of the districts along the Fatel Bara creek which enters the sea at the western extremity of Diu island deserve any mention. They are swampy sandy or muddy flats lying partly within tidal influence and traversed by small brackish water creeks.

The Okhamandal Ran.

The same may be said of the coastal alluvia seen in Okhamandal, the chief of which is the small Ran which separates Okhamandal from the main land of Kathiwar; it is a low muddy or sandy flat covered by brackish water, or salt water during the rains, or during high tides due to westerly gales.

The Gomti creek flat.

A swampy flat, nearly two square miles in extent, lies S.E. of Dwarka town at the mouth of the Gomti creek, and a similar one of rather smaller extent lies to the north of Dwarka at the mouth of the Rupen Bandar creek.

The Aramra flat.

Three miles north of the last-named flat begins another, which may be called the Aramra flat, and which extends along the coast for 13 miles, right up to the extreme northern extremity of the peninsula, with an average breadth of $1\frac{1}{2}$ miles and fringed along its western or sea margin with a line of blown sand hills. On its eastern side it forms two deep bays of very irregular shape.

The raised coral reef.

In its northern half, west of the Aramra creek, is to be seen protruding a feet or two above the general flat the surface of an upraised coral reef of apparently recent origin. The corals are chiefly of globular species, Meandrina and Porites, &c., but I have had no opportunity of determining any of them specifically. Madrepores were conspicuous by their absence. Between the coral masses is much dark muddy

silt in which occur many marine shells, amongst which many forms now living in the south Indian seas. Whether any extinct forms exist among the more northerly species with which I am much less familiar could not be determined without careful comparison of the specimens collected with a properly determined collection which I had no opportunity of doing.

This upraised reef is a perfect treasure-house for a marine biologist, and is deserving of full and careful study, for it is very rich in both corals and shells.

The reef can be traced south along the Aramra Dwarka road for over three miles to where the ground rises a little to the north of Bhimrana.

The several alluvial flats lying along the coast between Aramra and the N. E. corner of the Okhamandal peninsula beyond Positra are ordinary muddy flats with a fringe of mangroves along their sea-face.

3. *Subærial Formations*: *a. Soils and b. Blown Sands.*

a. Soils. By far the most widely distributed soil is the black soil, or regar, so commonly met with throughout the peninsula proper of India which, as already pointed out, is regarded by many geologists as an old forest humus—a view which obtains favour with the Russian geologists regarding the Tchornoizem, the famous black soil of South Russia, and with American geologists with reference to the deep soil of the prairies. Black soil spreads.

The black soil of Kathiawar offers, as far as my observation went, no special features different from those characteristic of itself in other parts of India. It occurs with rare exceptions on level or but moderately undulating ground.

Red and brown soils, which are the natural products of the weathering of rocks containing an appreciable percentage of iron, occur chiefly in the hilly tracts where the rocks are too continuous to admit of sufficient forest growth to form noticeable spreads of true humus. Red soils.

White alkaline soils are not of common occurrence in sufficient quantity to be worth recording, though some of the small rivers, *e.g.* The Shel in the Amreli Mahal, show a good deal of white efflorescence along the edge of the sand banks during the hot weather, proving that a good deal of alkaline matter has been in solution in their waters. White soils.

CHAPTER VI.

ECONOMIC GEOLOGY.

THERE is unfortunately but little to say about the economic value of the rocks and minerals found in the Kathiawar Gaekwari. In the total absence of metallic ores, practically speaking, and the entire want of carbon deposits, there is nothing to mention but rocks yielding building stones or stones suitable for road metal, but even of the former there is a remarkable lack of the more valuable and choicer sorts, such as fine marbles, granites, syenites, porphyries and serpentines. Of common building stones, however, such as basalt, miliolite and coarse shelly limestones and sandstones, there are practically unlimited supplies, as will be shown further on.

Basaltic rocks.

To take the more important stones in the order of their geological occurrence, the basaltic rocks come first, and they occur widespread and in great quantity all over the trappean area described in Chapter III., but do not seem to have found much favour in the eyes of the builders and architects of Kathiawar, for very few, if any, buildings of any pretensions have been constructed of them, and that probably for two reasons: firstly, because owing to their great hardness they are expensive to dress and, secondly, that from their dark, sad, colour they would make dark, gloomy-looking buildings. For rough work requiring strength they are very well suited and durable. The largest work for which they have to my knowledge been used is the wall of the town of Amreli. Considerable quarries of basalt exist and are still worked to the north of the Residency. Excepting the above mentioned and an old quarry on a large basaltic dyke at Gaodka 5½ miles S. W. of Amreli, where nearly the whole crest of the dyke has been quarried away, I did not notice any basalt quarries worthy of special mention in any of the central mahals, but hundreds of exposures of the rock exist on which quarry work might be advantageously opened.

Many of the dioritic dykes, such as those of Kátma, Akkadia Mota, and Jhália, all in Amreli Mahál, would afford opportunities for raising large blocks of valuable stone of great strength and durability, and of more pleasing colour than the average basalts. Their colour is a rich greenish black, much more pleasing to the eye than the dull greyish or blackish brown "sad" colour of the basalts. Diorite.

An exceptionally handsome stone is the slightly porphyritic diorite forming a flow S. east of Rupávati, the south-easterly outlying "tapa" of Damnagar Mahal. The rock is of a dark blackish colour with many felspathic grains of a warm green tint. I found no traces of this fine rock having been quarried, but it is well worthy of attention, as it would yield an excellent material for pillars, bases, steps, panels and other architectural objects. Rupàvati Diorite.

Amygdaloid traps are in the great majority of cases far too vesicular in structure to be of any use for even the roughest building purposes, and I noted only a solitary instance in which an amygdaloid was being quarried. This was in a small quarry a few hundred yards eastward of the town of Dhari. In this stone the amygdaloids were few and far between and detracted but little from its tenacity. Amygdaloids.

White marble is said to have been quarried near Jikiali and Samadhiala at the north-east end of Dhari Mahal, but I could hear nothing of its occurrence there on visiting the place. White massive calcite, which occurs in some quantity in a large vein south of the village, is probably the material meant, but it could be of little use, as it is largely permeated by strings and threads of a very hard white siliceous sinter, which would absolutely prevent its receiving a good polish. The vein seems to increase largely in size to the north-eastward beyond the Gaekwari frontier, and it is possible that there the calcite may be free from the siliceous sinter and be quarriable. At the foot of Lapala hill near Umria I picked up a good-sized piece of such massive white calcite which had formed part of a well-cut and slightly polished block, and my guide said such stone came from near Jikiali, but could give no further particulars. Marble.

Nests of such calcite occur mixed with much white siliceous sinter in the south-westerly extension of the Jikiali vein, but not in quarriable quantity or condition. Calcite.

Pipalwa calcite vein.

In only one of the calcite veins before referred to is the stone sufficiently free from siliceous matter to be polishable. This is in a vein shown in the map a mile and-a-half E.S.E. of Pipalwa and four miles S. of Lapála Hill; here the calcite forms a dense tough rock of a large grained speckly texture coloured mottled buffy white and grey, which could be dressed and polished into a handsome "marble." The vein can be followed for about a mile, and near its centre forms a double band, each division of which is from 2—3 feet in width. There are parts of the veins in which cherty sinter predominates over the calcite, or replaces it entirely, and where this obtains the vein is whitish in colour. No indication of this rock having been used could be found anywhere.

In none of the veins was calcite found that was pure and limpid and available for optical purposes. This was also the case with the calcite crystals found in small veins or strings follow joint-planes in basaltic flows to the N. E. of Dhrupnia three miles from Dàmnagar and to the S.W. of Ambaldi, also in Dàmnagar Mahal.

White siliceous sinter.

The white siliceous sinter, which often assumes a cherty texture, might be utilized by lapidaries for a variety of small ornamental objects, for it is frequently of sufficient hardness and density to take a very high polish which would show off its delicately-mottled surface to great advantage.

Coloured, jaspery chert.

Connected with the calcite veins in the eastern part of Dhári Mahal are irregular segregations of bright-coloured jaspery chert (referred to above at p. 161), rarely many inches in thickness, and, where exposed to atmospheric action very much broken up, but not much weathered superficially. The chert masses are often mottled or parti-coloured of various tints, *e.g.*, red, pink, violet, purple, blue, bluish white, greenish white and yellowish (rarely) of many shades and often of considerable beauty. These cherty bands are not, as far as I could ascertain, drawn upon by modern lapidaries, though they would furnish much material fit for working into a variety of small objects of ornament, such as are manufactured by the Jabalpur lapidaries, *e.g.*, ring and brooch stones, seals, paper weights, &c. &c.

Variolitic chert

The same remarks are applicable to the beautiful varioli-tic cherts, described at p. 160; they also appear to be completely neglected by the Cambay lapidaries, who appear to be a set of bigoted devotees of the goddess "Mamool," (hereditary fashion.)

Except for rough work such as stone fences and parapet walls to field wells, no use appears to be made of the material of the great acidic dykes such as those of Sakpur, Nigala and Dhalkania. I could see no traces of their ever having been quarried, though in many parts of their courses they would yield stone of great beauty for high class buildings. The only two acidic dykes on which I met with quarries are those lying south of Damnagar (see p. 153). The stone raised here would appear to be used only in the rough and to be covered over with cement and white-wash, for though in the case of the quarry at Damnagar stone had been freshly quarried, I came across no buildings constructed of it.

Miliolite or Porbandar stone.

From the apparent neglect of useful building stones prevailing in the Trappean Mahals of the Gaekwari, it is a pleasure to turn to the evident appreciation of the local stone to be seen in the Nagher district, or Kodinar Mahal, where many extensive quarries have been since remote periods worked in the miliolite limestone. This most useful stone is known in the trade and to most residents in, or visitors to, Bombay as "Porbandar stone," as it is exported to a considerable extent from the port of that name. The true "Porbandar stone" is a typical miliolite which is largely raised in extensive quarries lying to the N.E. of the town at the foot of the Barda hills. I visited these quarries when at Porbandar under the kind and courteous guidance of Mr. Benson, the Chief Engineer of the State, and enjoyed the great advantage of having everything of importance connected with the local industry pointed out to me by very competent authority. The town of Porbandar shows signs in every direction of the benefit it derives from an unlimited and cheap supply of high class building stone. Many important improvements to the place were in progress by free use of the miliolite under Mr. Benson's able management.

Kodinar miliolite as good as Porbandar stone.

Having previously made a careful study of the principa miliolite quarries in the Kodinar Mahal, I was in a positio to form a fair opinion as to the relative merits of the ston occurring in the two States, and the conclusion I arrived at i that the best miliolite raised at Harmaria, Advi and Dolás in the Kodinar Mahal is quite equal in quality with th best class stone obtained in the Porbandar quarries, an that very large supplies of the best quality stone ar obtainable by judicious quarrying operations.

Proposal to export the miliolite.

The quantity of stone of a quality but very slightl inferior to the best that could be raised is vastly grea and practically inexhaustible. This great wealth c marketable stone necessarily suggests the thought how t send it best to the greatest markets, which are Bomba and the other large towns of the Western Coast, which ca be so easily reached by sea if the stone can be brough down to the coast with ease and put on board ship in safe harbour. Such a harbour already exists on a sma scale.

Velan Bandar Harbour.

Velan or Marwar Bandar which lies on the north-east sic of the Diu Head, the head land which forming the southern most point of the Kathiawar Peninsula, which juts out ha a mile from the land east of it and being[1] backed by low hill, affords very good shelter for small craft. Th protected area is at present some 2 or 300 acres in exten and if a breakwater were thrown out from a little with the extreme point of the head land to the N.E. by E., th protected area could be made very much larger. The con struction of such a breakwater offers no insuperable difficult seeing what has been done at Colombo. The breakwate would not be exposed to the direct impact of the waves, fo the latter would impinge upon it at an acute angle and thu exercise the minimum of force against it. Velan Band

[1] The possibility of converting Velan Bandar into a "very good ha bour" had already struck the writer of the note on "Mul Dwarka" in t *Kathiawar Gazette* (published in 1884), and doubtless others before hi I had not seen his remarks when I visited Diu Head, but the view acro the little bay from the top instantly suggested the idea that here w the harbour from which a large trade in that most useful stone could started. The slope of hill north of the lighthouse would offer a cool a healthy site for the residence of the harbour officials well raised above th swampy flat round Velan villages.

thus altered would become a very valuable harbour of refuge on a coast where it would be an immense blessing. My visit to Diu Head and Velan Bandar was made in the middle of March, 1894, when a stiff south-westerly breeze was blowing and the sea to the south of the Head was distinctly rough, but the waters of the bay under the lea of the Head were perfectly smooth. Only a few days before a couple of B. I. S. N. steamers on their way from Bombay to Karachi, with troops, had put into the little bay and lain there perfectly sheltered for some time. The little bay was used as a haven early in the century by ships of the Bombay Marine, and Captain Grant commanding the Gaekwar's Marine employed in suppressing piracy, had a small bungalow at the village of Velan a mile N.W. of the bay. The bungalow still stands and is shown on the topographical map as Grant's bungalow. A small creek enters the bay from the west, and the flat which it traverses could very easily be excavated to make a large dock into which all manner of craft could go to be loaded or for repairs. The quarries of good miliolite nearest to Velan Bandar bay are those at Advi and Dholasa, which lies 9 and 11 miles, respectively, to the N., and from them the stone could easily be carried down by a light tramway across a perfectly flat stretch of country offering no engineering difficulties of any moment.

If it were decided to construct the breakwater I have hinted at, abundance of suitable stone could be quarried on the N. side of the Diu Head hill within half a mile of the point where it would have to be thrown into the sea, or it could be converted into concrete blocks on any scale desired.

If the improved Velan Bandar harbour came to pass, it might well become the starting point for a light line of railway into the central part of Kathiawar, and the harbour being a safe one would speedily attract shipping and trade, and cut out Porbandar, Veerawal and the Kodinar road-stead, none of which can from their geographical situations ever become safe or commodious harbours.

Brown limestone of Shedaya.

Strongly contrasting in both its colour and texture with the white and oolitic thick-bedded miliolite is the brown

slightly gritty flaggy limestone of Shedaya, which would lend itself capitally for use with the former in large and ornate buildings. If, as I suspect, it underlies the miliolite, there will very likely be a far larger development of it than indicated merely by the limited patch which shows through the cotton soil N.E. of Shedaya. It might be as well to test this question by a few small excavations through the black soil.

The method of quarrying in use.

The mode of quarrying the miliolite deserves a brief notice, as it is peculiar and applicable only to a soft rock. The rock is cut with adze-shaped picks, by means of which deep grooves are cut into the general mass of rock to the required depth and the intermediate mass then broken out with wedges.

The rock is in some quarries, *e.g.*, at Harmaria and at Chuwán-ni-Khán, near Kodinar, so homogeneous and so compact that faces of rock from 25 to 30 feet high remain standing, even though they overhang by several feet, from their bases, having been excavated by the quarrymen. This is unlike the thin or thick flagged character of the Porbandar miliolite.

The broken out stone is dressed with adzes, axes and chisels as the case may require. For building purposes it is generally cut into brick-shaped masses. Three sizes of these were being prepared at Harmaria quarry :—

Size 1, 14 to 15 inches long by 12 wide and 4 to 5 thick.
„ 2, 18″—20″ long by 15—16 wide and 5 to 6 thick.
„ 3, 2′ „ by 16″—18″ „ „ 6″ „

Price of the stone.

Size 1 was selling for 5 Rs. per 100, size 2 for 7 Rs., and size 3 for 10 Rs.

Large-sized masses could be broken out and worked when required, as is done at Porbandar for the Bombay market.

As already pointed out when dealing with the fine Songir sandstone in Chapter IX. of Part I., the system of quarrying now in vogue is a very bad one and leads to great waste and unnecessary labour, which might very easily be prevented by the introduction of a better system. Much might be done immediately by introducing the use of saws for cutting up large masses.

With a well-organized quarry department and the provision of a few light tramways down to the proposed Velan

Bandar harbour, a very profitable State monopoly in the stone trade might be very easily organized. The advantages of having a good harbour on the south coast of Kathiawar, which is now so repellent to the mariner, are so obviously great that there is no need to insist on them any further, but the opening up of the stone trade need not wait for the construction of the proposed breakwater; the anchorage for small craft at the western end of the bay is already so well sheltered from the dangerous westerly winds that the construction of a good quay with a jetty, or better still a small stone mole projecting southward from the N. side of the bay is all that is immediately required.

The stone-carrying craft could lie behind the mole protected from the swell caused by a casual S.E. wind, which is the only one that can blow right into the bay, and such S.E. winds are, I was told, of rare occurrence.

The mole would make a capital terminus for the tramway from the Dholasa and Advi quarries, and on it the stone brought down could be most conveniently dumped close to the cranes to lift it on board.

The construction of the breakwater would of course make the harbour perfect and protected against all winds from the seaward.

Okhamandal limestones and calcareous grits.

Okhamandal, as already pointed out, abounds in coarse, gritty limestones and shelly calcareous sandstones which yield but indifferent stone for fine work, but do well enough for coarse work. The great temple at Dwarka is said to have been built of the stone raised from the many shallow pits N. and N.E. of the town. This is quite likely to be true, but as Europeans are not allowed to go near the temple, I could not examine closely the material it had been built of, but it appears to be a shelly calcareous sandstone. It is a great pile with a tall tower, but by no means a fine specimen of Hindu architecture. The only elegant building at Dwarka is the Rukmini temple close to the Rupengudi creek.

Rajpura breccia limestone.

The best qualities of limestone I saw in Okhamandal are the brecciated variety seen in the rocky hillocks described (p. 163) as occurring at and to the south of Rajpura Bandar on the S. side of Beyt harbour; it is strong, fine-grained grey stone of pleasing appearance.

At Positra. Of good quality also is a hard shelly limestone occurring on the top of the cliff to the S.E. of Positra.

South of Bardia. The only limestone suitable for decorative purpose that I noticed in Kathiawar is the dense shelly variety described (p. 164) as occurring at the lower south-western end of the valley stretching down to the sea from the village of Bardia. If the pleasing pinkish yellow colour of the surface prevails through the mass of the stone, it would make a very pretty yellow marble very suitable for vases, slabs, pedestals and other ornamental objects.

Lime. Lime can be procured in abundance by burning many of the limestones or the coral of the Aramra reef.

Iron ore. A clayey iron ore of poor quality occurs near Kalianpur, but even if rich it would be of no value, as there is absolutely no timber in Okhamandal of which to make charcoal wherewith to smelt the ore.

Marl. The pretty red marls occurring along the eastern coast of Okhamandal might be utilized for making a bright and pleasing colour-wash.

Gypsum. Sulphate of lime occurs in good and pure crystals in clay beds at the southern extremity of the Okhamandal peninsula, a mile westward of the village of Kuranga (p.164). The crystals occur in good numbers, and might be collected in fair quantity if any demand for them existed. If carefully washed and prepared, they should yield plaster of Paris of excellent quality.

As the Okhamandal province has no special staple for export, and the town of Dwarka appears to depend entirely on the pilgrim trade, the want of a harbour is an evil not much felt, but it is one that could be most easily met by the construction of a light tramway to Aramra and of a pier from which boats could ply to Beyt town and back direct at any time of the tide.

The construction of a breakwater to protect the entrance of the Rupangudi creek N. of Dwarka from the direct action of the great rollers which break on the coast as long as the westerly winds prevail should not be an engineering work of very great difficulty, and abundance of the coarse shelly sandstone occurring close by could be quarried in blocks of the requisite large size within a few score yards of the beach.

APPENDIX No. I.

The Agate Mines of Rattanpur.

The circumstances under which the Agate beds occur in the south of Velachha and the north of Kamrej Taluqs are rather dissimilar to those in which the famous Rattanpur beds are met with in the Narbadda valley, east of Broach. In the former case the beds occur close to the bottom of the nummulitic series and rest directly on the laterite which forms the actual basement bed. Whereas at Rattanpur the agatiferous beds lie considerably above the base of the series and are underlaid by other gravel beds of considerable but uncertain thickness.

The agate gravels near Naroli Nahani in Velachha Taluq are so greatly obscured by the overlying cotton soil that it was impossible to form any idea of their surface appearance, but they are in all probability like the agate gravels further south near Galha, unconsolidated or only half consolidated beds of coarse gravel, with much small gravel or sand intermixed. The Rattanpur gravels on the contrary are much less coarse and more generally consolidated than the Galha beds. The latter contain a much larger number of large pebbles of agate heliotrope and coloured cherts than the Rattanpur beds, and would for that reason be, in all probability, far more valuable if these larger stones were exported to Europe, where such large stones would be far more appreciated than they are by the Cambay lapidaries, who are intent only on working up the common small agates for the China market.

I do not think the Naroli Nahani or Galha beds would need to be mined by pits as at Rattanpur; they could be worked by simple digging. Whether the smaller grey agates occurring in the beds would be improved by burning would have to be ascertained experimentally. Mr. Ginwalla, the present contractor for the Rattanpur mines, had visited the Galha beds and formed a bad opinion of their value from the comparative paucity of the small grey agates so largely found at Rattanpur, but I think they were far too little exposed to form a reliable estimate of their value by mere cursory inspection, and he did not seem to have perceived the far greater richness of these gravel beds in large agates, heliotropes (bloodstones) and richly coloured cherts. The beds should not, I think, be offered by public auction, but be worked by the State, and the valuable stones collected be offered for sale at intervals, subject to the superintendence of the Chief Engineer of the State.

My visit to the mines.

In order to gain a better idea of the economic value of the agate gravel beds of Naroli Nahani and Galha, I visited the famous agate mines at Rattanpur in Rajpipla State with the approval of His Excellency the Dewan. The information gained was interesting but not conclusive, as so much of the value of the agates depends upon the fancy of the Cambay lapidaries, and this, in its turn, is founded upon the China market, which takes the greater part of the whole outturn.

The stones dug out at Rattanpura and most highly valued at Cambay are not those which would rank highest in the estimation of European Collectors and mineralogists, but very much smaller stones which I should intuitively have set down as of fourth or fifth grade.

I visited the mines out of which the desired kinds of agates are dug in the company of Mr. Ruttonji Nowroji Ginwalla, the Akik contractor, who was most courteous and obliging and showed me everything connected with the raising of

the "Akik" stones and their preparation for the Cambay market. He also kindly furnished me with a list of the names and descriptions of the principal varieties, twelve in number, of agates recognized by the dealers and lapidaries, which list I give in the note below :—

List of varieties recognized.

1.	Jerda	Thin skins (outer crusts) a very bright colour, very rare.
2.	Maddaya	
3.	Mactária ...	White and bluish.
4.	Lambi dunghi.	Good colour, red.
5.	Rodi damli ...	Do. do. small.
6.	Moti damli ...	The common kind.
7.	Asli	White to yellowish after baking.
8.	Baman	
9.	Devna pug.	
10.	Datára ...	White.
11.	Bimpor ...	Large agates, rare.
12.	Pipodra ...	Poor stones.

Unfortunately I was unable to see Mr. Ginwalla again after receiving this list from him and to ask him some questions about it, but I give it at length, as it may possibly prove useful to the officials who may have to deal with agate dealers.

The pits sunk to reach the gravel bed containing the desired class of stones are simple shafts from 25 to 30 feet in depth, but rarely more. The shafts are rarely more than 2½ feet in diameter, and the miners descend by means of holes in the sides 3 to 4 inches deep, into which they thrust their feet and hands. No ladders were in use in those I saw, which were rather numerous and scattered without plan through the thin small tree jungle. Like the old Deneholes, or chalkmines in Sussex and Essex, the shafts are at their base expanded into small chambers whose size varies according to the firmness of the gravel bed reached.

The whole process looks rude and dangerous, but Mr. Ginwalla told me that accidents are of very rare occurrence, as the gravel beds are very fairly consolidated by a rather ferruginous sandy matrix.

The stones raised were carried from the pits in baskets by coolies to Mr. Ginwalla's bungalow at Limodara, where they were sorted and underwent a process of slight baking in open earthenware pots covered with small fires of dry cowdung, after which they would be sorted again finally and slightly chipped to see what had been the effect of the baking. The general action of the firing appears to be an intensification of the internal colouring of the stones especially in respect of red tints.

I would very gladly have made a careful examination into the lapidary's industry at Cambay, but no opportunity for doing this presented itself.

An elaborate account of it is, I believe, given in the volume of the *Bombay Gazetteer*, in which the State of Cambay is described, but I have been unable to get sight of it. I cannot help thinking that there must be some lapidaries at Cambay capable of turning out much better work than what was produced by the Baroda workshop which I referred to at page 140 of the first part of this Memoir. If not, it is very hard to understand how the industry acquired the reputation which it undoubtedly enjoys at present.

The first published account of these interesting mines is that given by Mr. John Copland in the *Transaction of the Literary Society of Bombay* (Vol. I., p. 289, 1819), from which I give some extracts of interest, as he noted several facts which did not come under my observation, or else some things connected with the mines must have changed in the long interval of nearly 80 years which intervened between our respective visits. His remarks as to the colours of the stones found and the changes they undergo are quite in agreement with my later observations, but among the stones collected I noticed nothing but agates,

to heliotropes,[1] mocha stones or jaspers, all of which occur commonly in the agate gravels in Velachha and Kamrej Taluqs. But other pits may very probably produce these as well, though I happened to see none, and was much struck by their absence. No mention was made to me by Mr. Ginwalla of the presence of "fire damp" in the pits, nor of accumulations of foul air rendering them unsafe for the mines, and I certainly think that the testimony of (although negative) of an educated and very intelligent man like him should be preferred to the mere assertion of an ignorant man as in all probability was Mr. Copland's guide, whom he describes merely as a miner.

I had not seen Mr. Copland's paper before my visit to the mines, or should certainly have made very special enquiries on this point. In the absence of carbonaceous matter in the gravels, it is most improbable that either fire-damp or choke damp should accumulate in the pits.

Account of the Cornelian mines in the neighbourhood of Baroach in a letter to the Secretary from John Copland, Esq., of the Bombay Medical Establishment:—

EXTRACT.

"On account of the tigers with which the country abounds, no human habitations 'were found nearer the mines than Rutunpoor, which is seven miles off. The miners 'reside at Neemoodra, where alone the stones are burnt. The mines are in the wildest 'part of the jungle, and are very numerous; they are shafts working perpetually 'downwards, about four feet wide: the deepest we saw was 50 feet; some extend in a 'horizontal direction at the bottom, but in consequence of the earliness of the season 'few had reached a depth sufficient to render this turn necessary, and in those that had 'it was not carried many feet. In using the term 'earliness of the season,' it is 'proper to mention that the nature of the pits is such as to prevent their being worked 'a second year on account of the heavy rains which cause the banks to fall in, so that "new ones are opened at the commencement of every fair season. We arrived at the "mines about seven o'clock A.M., when none of the workmen had come except one, who "accompanied us as a guide from Neemoodra. We were informed that the fire-damp " (hydrogen gas) was not uncommon in the mines, and that the miners did not descend "till the sun had risen sufficiently to dispel the vapours. We went to the bottom of "one pit, about 30 feet deep, without any assistance from ropes, or ladders, by means of "small niches for the feet and hands on opposite sides of the pit, but understood that "the miners always made use of a rope to hold by, of which we could not avail our-"selves, as the workmen at the close of their labour carry to their homes the simple "instruments of their vocation, together with the stones which the day's labour has "acquired. The soil is gravelly, consisting chiefly of quartz sand reddened by iron and "a little clay. The nodules may weigh from a few ounces to two or even three pounds, "and lie very close to each other; but for the most part distinct not in strata but "scattered through the mass and in the greatest abundance. I saw none of a red "colour at the mines; some were blackish-olive like common dark flints, others some-"what lighter, and others lighter still with a slight milky tinge. The first our guide "informed us would be black when burnt, the second red, and the third white. In "this he may have been correct; but I doubt the fact as to the first, which we found in "a proportion inconsistent with the well-known rarity of a black cornelian. I sent " specimens of each to Captain Hall of the Royal Navy, whose zeal in all scientific " researches I doubt not has settled this point. I confess myself of opinion that there " can be no precise rules drawn from the appearance of the stones before, for that " which they will assume after burning, because it depends partly on the degree of heat "they undergo.

"A red cornelian by an intense heat will become white; but as far as my observations "go, no stone of the former colour is found so in the mines (excepting jaspers), although "a large proportion of them assume it at Neemoodra. Many also, after having been "burnt, show both colours sometimes distinct and sometimes mixed, and of a pinky " blue; while the colour was uniform, or very nearly so, in all which I remarked at the

[1] Copland mentions Hæmatites chiefly of the brown and green (with red spots) varieties, which was doubtless a slip for heliotropes, as was pointed out already by Dr. H. J. Carter in his summary of the Geology of India when speaking of the "Cornelian Conglomerates" (p. 751).

"mines. The lightest-coloured stones came out of the fire of a much more delicate and "transparent white than before, and often surrounded by a cortex of red, but without "any distinct line separating the colours. We were unfortunate in the time of visiting "Neemoodra, for all the good stones had been removed and only a few heaps of refuse "left. I saw none imbedded in rocks as flints are in chalk; some nodules on being "broken showed a mixture of quartz and agate, and others in a crust of quartz minutely "crystallized on the inner surface contained a black oxide of iron of a powdery appear- "ance, many pieces of which we found by themselves in the gravel. Hematites chiefly "of the brown and green (with red spots) varieties, mocha stones and jaspers of various "colours are very common here; indeed the last was found in almost every part of the "province we visited on our route; each stone is chipped in the mine to discover its "quality, and those which are approved separated from the refuse, heaps of which lay "at the mouth of every pit which had been worked.

"I shall now attempt to give an account of the mode in which the cornelians undergo "the action of fire, as derived from the testimony of a respectable native attached to "the adawlut at Baroach, who was formerly in the cornelian trade, and had himself "superintended the process at Neemoodra; his account is corroborated by our personal "observation, and by what we learned on the spot.

"The stones are brought to this village every evening, spread on the ground, exposed "to the sun to prepare them for the further process, and turned every fifteenth day till "the time of burning, which is only once a year, one month before the commencement "of the monsoon. They are then put into round earthen pots about fourteen inches in "diameter, the bottom of which have been taken out, and the pots inverted (mouth "downward); the pieces taken from the bottoms are put inside and placed over the "mouths to prevent the stones falling out; in this state the pots are placed side by side "in a trench of indefinite length, but of which the depth and breadth are about two "feet having a layer of five or six inches of dry goat's dung below, and the same above "the pots.

"This is set on fire about eight o'clock in the evening. All the fuel is consumed before "daybreak, when the pots are removed from the trench to the open air for the stones "to cool which requires about three hours; after this they are taken out of the pots "piled in heaps and again chipped for the same purpose as when taken from the mines, "and are finally thrown into a pit where they remain till called for (more to be out of "the way of thieves than as constituting any part of the operation). From Neemoodra "the cornelians are carried to Cambay by the merchants who come from thence, where "they are cut and formed into the beautiful and much sought after ornaments peculiar "to the place.

"I ought to mention that the miners do not forsake a pit on meeting with a spring, "but merely change the direction—the water never rising to any great height."

APPENDIX No. II.

GLOSSARY

Of Technical Terms and Names used in the Memoir.

As this Memoir will doubtless be placed in the hands of many who have not done any previous geological reading, a glossary of the technical terms and names which have been unavoidably used can hardly fail to be valuable.

Acicular—(*Acicula*, a little needle). Needle-like, long and fine; a term applied to crystals.

Agate—(Derivation said to be from the river Achates in Sicily). A variegated form of silica, banded with different colours, or with opaque and translucent layers alternating. It is commonly found lining cavities in basalt and other volcanic rocks Called Akik by Indian lapidaries.

Agglomerate—Ejected, blocks of volcanic rock cemented together into a breccia rarely into a conglomerate.

Albite—(*Albus*, white). A kind of felspar, usually of a white or grey colour, and differing from orthoclase or common felspar in containing soda instead of potash, and in crystallizing in the triclinic, or anorthic, system.

Alluvium—(*Alluo*, I wash against). Clay, silt, sand, and gravel deposited from water. The term is usually restricted to deposits from rivers, lakes, and seas, still existing, or which existed in very late geological times; and it is especially applied to the deposits formed by rivers when overflowing their banks.

Allumina—An earth; the sesquioxide of the metal aluminium, containing two equivalents of the metal and three of oxygen. Alumina combined with silica is the basis of all clays.

Amethyst—(ἀμέθυστος). Quartz or rock crystal, of a pink or purple colour, the colour being due to the presence of manganese or iron.

Amorphous—(*a* privative, and μορφή form). A term applied to such mineral substances as present no appearance of crystallization.

Amygdaloid—(αμυγδαλον almond; εἶδος form). A volcanic rock containing nodules (generally small) of quartz, felspar, zeolite, or some other mineral. These minerals have been deposited in cavities which were originally, in most cases, air-bubbles in molten rock.

Analcime—(ἀνάλκις, weak; in allusion to its weak electric power when rubbed). A zeolite composed chiefly of silica, alumina, and soda, and crystallizing in the cubical or monometric system. The ordinary form is a trapezohedron.

Anamesite—(αναμεσος, intermediate). A fine-grained variety of dolerite or basalt, in which the constituent minerals are so minutely crystallized, that the rock appears homogeneous, except under the microscope.

Andesite—A variety of trachyte, first described from the Andes, consists of Andesin felspar, glassy felspar and hornblende disseminated through a dark coloured base.

Anticlinal—(*ἀντί*, opposite, and *κλίνω* I incline). The curvature of strata in a ridge-like form, the convexity or salient angle being upward.

Anticlinal axis—A line drawn along the summit ridge of an anticlinal curve.

Apophyllite—(*αποφυλλίζω*, I exfoliate). A hydrous silicate of lime and potash, with some fluorine; allied to the zeolites, and occurring in the same manner as zeolites in volcanic rocks. It crystallizes in the tetragonal, or pyramidal system.

Aqueous rocks—(*aqua*, water). Rocks deposited by water, in contradistinction to igneous rocks, the formation of which has been due to heat.

Arenaceous—(*arena*, sand). Sandy, or composed of sand.

Argillaceous—(*argilla*, clay). Composed of clay, or containing a large proportion of it.

Arkose—A detrital rock, composed of the materials of decayed granite in angular fragments quartz, felspar, and mica, and forming a gritty rock often hard to distinguish at first sight from weathered granite.

Ash, Volcanic—A general name applied to fragments of rock and dust (lappillæ, scoriæ, etc.) ejected from volcanoes. When consolidated, the mass forms a brecia, consisting of larger and smaller masses of various igneous rocks, such as basalt or trachyte, &c., in a finer matrix.

Augite—(*ἀυγή*, lustre). A mineral known also as pyroxene; one of the principal constituents of lavas, and especially of dolerite. It is composed of silica combined with lime, magnesia, iron, and other basis in varying proportions. Augite differs but little in composition from hornblende, and both crystallize in the same system, the oblique or monoclinic, but the angles differ.

Azoic—(*ἀ* privative; *ζωή*, life). A term applied to the oldest rocks in which no organic remains have hitherto been discovered.

Basalt—(*basaltes* Gr. Lat.) An igneous rock, composed of augite and labradorite, and often with olivine in disseminated grains. The term is chiefly applied to the hard black crystalline form of dolerite, and especially to that variety of the rock which exhibits prismatic structure.

Basin—A defined area composed of strata, dipping in a concave form from the circumference towards the interior.

Basset or Basset-edge—A miner's term for the outcrop of a bed.

Bed—A single definite layer of a sedimentary rock, irrespective of thickness.

Botryoidal—(*βότρυς*, a bunch of grapes; *εἶδος*, form). Minerals and rocks are thus termed when, owing to concretionary structure, the surface is raised into numerous convex projections resembling grapes.

Boulder—A mass of rock transported by water action too large to be classed as a pebble.

Breccia—(Italian). A rock composed of angular fragments cemented together.

Calcareous—(*Calx*, lime). Composed of lime, or containing a considerable quantity of it.

Calcite—(*Calx*, lime). Mineral carbonate of lime, crystallizing in the hexagonal system.

Cañon—(Spanish). A narrow river gorge with high precipitous sides.

Chalcedony or **Calcedony**—(Derived from the town of Chalcedon). A riety of uncrystallized silica with a waxy lustre, and either transparent translucent; generally bluish white or white in colour.

Chert—Impure silica, or flinty portions of rocks.

Chlorite—(χλωρός, green) a hydrated silica of alumina, iron and magnesia, embling mica, but of green colour and very soft, occurs chiefly in scales t small crystals in metamorphic rocks. Forms a large constituent of orite schist.

Cleavage—A fissile structure, not due to the original bedding of a rock, , as a rule coincident with it. Cleavage is characteristic of true slates, has been shown to be due to pressure exercised at right angles to the vage planes.

Conformable—Beds having their satisfaction planes perfectly parallel, in which the lower has not been eroded before the deposition of the er.

Conglomerate—(*Con*, together, and *glomero*, I collect). Rocks composed ounded pebbles cemented together, or imbedded in a sandy argillaceous alcareous or ferruginous matrix.

Coral—(κοράλλίον). A general term for the calcareous structure secreted Anthozoa and Hydrozoa.

Coral reef—A shoal or low island formed by the growth of corals, and the accumulation and consolidation of their débris. In many tropical s, archipelagoes of great extent are entirely formed of coral reefs. These e been shown to have been built upon submerged land, the reef-building al animals which can only at certain moderate depths, having gradually t up the island as the base sank.

Cretaceous—(Creta, chalk) a system of rocks called after the chalk form- n which is one of its most important member.

Crop—Crop out. To appear at the surface. See "Outcrop."

Crystal—(κρύσταλλος, ice). A mineral or salt having regular polyhedral ucture. All crystalline forms known are divided into six systems: the ical or isometric; the pyramidal, dimetric, or tetragonal; the prismatic, metric, or orthorhombic; the hexagonal or rhombohedral; the mono- ic or oblique; and the triclinic or anorthic.

Debacle—(French). A huge rush of water caused by the sudden giving of some dam whether natural or artificial.

Debris—(*Débris*, fragments of wreck). An accumulation of loose erial derived from the waste of rocks.

Degradation—The wasting and wearing away of rocks by atmospheric queous action.

Delta—The alluvial land near the mouth of a river. The name was inally given to the triangular tract near the mouth of the Nile, was derived from the resemblance of this area in form to the Greek er Δ.

Denudation—(*Denudo*, I lay bare). The removal of the superficial crust he earth by the agency of the atmosphere and water.

Deposit—(*Depono*, I lay down). Any substance originally suspended issolved in water and precipitated therefrom.

Detritus—(*Detero*, I rub off). Material removed by disintegration and other agencies from the surface of rocks.

Diaphanous—Transparent.

Diorite—(διοραω, I distinguish). A rock, naturally fine-grained, of a dark-green colour, and consisting of felspar (not orthoclase) and hornblende.

Dolerite—(δολος, a trick or deceit). A rock of volcanic origin, composed of labradorite and pyroxene, and distinguished from trachyte and its allies by the much larger proportion of bases to silica.

Dune—(French). A sand-hill raised by wind action.

Dyke—A rough stone wall. Volcanic or plutonic rock (trap), filling a longitudinal fissure in a pre-existing formation.

Eocene—(ἠώς, dawn; καινος, recent). The lowest great sub-division of tertiary strata.

Eolian—(*Eolus*, god of the winds). A term applied to wind-carried formations, such as blown sands.

Erosion—(Eating or gnawing away). Refers to the action of moving water.

Escarpment—An inland cliff, usually produced by the outcrop of a hard stratum.

False bedding—Oblique lamination; the arrangement of sand and other materials of which a bed is composed in laminæ not parallel with the planes of bedding. False bedding is especially common in beds of sandstone deposited by running water, as by a river, or by tidal currents in the sea.

Fault—A miner's term for any break in the continuity of a coal seam or mineral vein, however caused. In geology, the name is only applied where fracture of any rocks has taken place, accompanied by the shifting, either vertical or horizontal, of the opposite faces of the crack.

Felspar or **Feldspar**—(The latter spelling is correct, the word being derived from the German *feldspath*). A very important group of minerals, one or the other species being a principal constituent of almost all igneous rocks. Orthoclase, albite, oligoclase, and labradorite are felspars: all consist of double silicates of alumina and one or more alkalies or alkaline earths, and crystallize in the oblique or anorthic system.

Felsite or **Felstone**—A rock of compact texture, usually pale coloured, but sometimes black or brown, weathering white, composed chiefly of felspar with some quartz. Felsite is the matrix of most porphyries.

Ferruginous—(*Ferrugo*, iron rust). Impregnated with iron oxide.

Flag or **Flagstone.**—Hard laminated, or fissile stone, especially hard sandstone in thin slabs.

Flint—Silicious concretions, usually translucent and tolerably homogeneous, occurring in chalk or lime-stone.

Foliation—The arrangement in alternating laminæ of different minerals, occurring commonly in gneiss and other metamorphic rocks.

Foraminifera—(Foramen, a small opening; *fero*, I bear). A group of *Rhizopoda* living in hollow perforated shells, frequently chambered. Globigerina, Alveolites and nummulites are examples.—See *Rhizopoda*.

Formation—An assemblage of rocks of similar origin, connected by mineral characters, by organic remains, or by being of the same geological age.

Fossil—(*Fossilis*, dug out of the earth). Originally, this term applied to all mineral substances; now, it is restricted to organic remains, animal or vegetable, imbedded in rocks.

Freestone—A stone, usually a sandstone, easily cut and dressed.

Gabbro—(Italian). A rock composed of labradorite and diallage, or of bronzite (bronzite). It is frequently associated with serpentine.

Garnet—(*Granatus*, like a grain). A mineral crystallizing in the isometric or cubical system, and composed of silicate of alumina and lime, or of iron; the alumina often replaced by sesquioxide of iron, and the lime by magnesia or some other oxide.

Gasteropod—A family of mollusca or shell fish that walk upon the extended base of the foot.

Ghat—(Hindi). A landing-place, ford, or pass. The term "ghâts" originally applied to the passes through the mountain-ranges that run parallel, or nearly so, to the coasts of the peninsula, has now been transferred to the ranges themselves.

Gneiss—(A German miner's term). A highly foliated rock, composed of quartz, felspar, and mica in crystals. The mica is sometimes replaced by hornblende, and garnets, or other minerals are imbedded. Gneiss passes by insensible gradations into granite.

Granite—A plutonic rock, rich in silica, and composed of felspar, quartz, and mica. The felspar is almost always orthoclase; a second felspar, usually oligoclase, being frequently present also. In some forms of granite the mica is absent (aplite or pegmatite).

Gravel—Loose pebbles, with or without sand.

Green-earth—A hydrous silicate of iron and potash, found chiefly in basalt and other eruptive rocks.

Greenstone—A general name for igneous rocks, composed principally of felspar and hornblende. By some writers certain plutonic rocks containing diorite are also called greenstones.

Grit—A coarse sandstone, or, according to some writers, a sandstone in which the grains of quartz are angular. The term is applied somewhat variously.

Group—An association of beds agreeing in mineral character, or varying amongst themselves in mineral character, but containing the same fossils. The terms "group" and "series" are frequently used by geologists as equivalent terms.

Gypsum—(γύψος, lime or chalk). Hydrated sulphate of lime crystallizing in the oblique system.

Hæmatite—(Greek) αἷμα, blood). Native iron oxide in a massive form, or crystalline or amorphous. The crystalline variety, known as specular iron, crystallizes in the hexagonal system.

Hornblende—A silicate of various bases, usually lime, magnesia, or iron, or combinations of these with each other, part of the silica being often replaced by alumina. The crystallization is oblique. Hornblende is an important constituent of many igneous rocks, such as syenite, diorite, etc.

Hornstone—A variety of flint or chert, resembling horn in appearance.

Hypogene—(Greek) ὑπό, below; γίγομαι, I am made). A term proposed by Lyell for the metamorphosed sedimentary formations formerly known as

primary. The term is extended to express the idea that the beds in question has been transformed from below.

Igneous—(Latin, ignis, fire). A term applied to all geological phenomena supposed to be due to the action of the heat. Igneous rocks are such as are believed to have undergone fusion. Particular igneous rocks were formerly supposed to be characteristic of different geological epochs, and some foreign geologists still believe in the distinction, which has, however, been entirely abandoned by all the best English writers.

Inlier—An exposure of an underlying rock through the overlying stratum.

In situ—(Latin, in place). A term applied to a rock or fossil when still in the exact position in relation to the matrix or surrounding rocks in which it was formed or deposited.

Ironstone—Any ore of iron; but generally the name is employed for carbonates, especially the argillaceous carbonate of iron so common in the coal-measures, and generally known as "clay ironstone."

Jasper—Impure opaque coloured quartz, often of a bright red colour, or striped red and black or white.

Jhil—(Hindi). A marsh or shallow lake.

Laterite—A cellular ferruginous clay, either of sedimentary origin, or formed by subaerial weathering of ferruginous rocks.

Lava—(Italian). The molten rock that flows from a volcano in eruption. Lavas have the same composition as intrusive volcanic rocks, and are divided into two great sections, (1) doleritic, or basic, consisting largely of pyroxene, and not containing more than 45 to 55 per cent. of silica; and (2) trachytic, or acidic rocks, with 60 to 80 per cent. of silica, and composed mainly of felspar.

Limestone—Indurated carbonate of lime.

Loam—A soil composed of clay and fine sand.

Loess—(German) A term applied to a very fine unstratified or imperfectly stratified formation, composed of clay, very fine sand, and some carbonate of lime, occurring in the Rhine valley. Similar beds of great thickness have been found in China and other parts of Central Asia, and shown to have been probably formed of fine dust transported by the wind.

Lydian stone—A black siliceous rock, either a kind of jasper, or an altered very fine grained siliceous shale.

Magnetite—Magnetic iron ore. An ore of iron composed of one equivalent of sesquioxide and one of protoxide, or of three equivalents of iron and four of oxygen. It crystallizes in the isometric or cubical system, and is usually found in octohedra.

Marble—Properly this term is only applied to the finer and more crystalline forms of limestone. Commonly, however, all rocks capable of being polished are thus called.

Metamorphic rocks—(Greek μετά after; μορφή form). Rocks which have undergone a change of structure and become crystalline. The term is especially applied to sedimentary formations, which, through the agency of heat or chemical action, have acquired crystalline structure.

Mica—(Latin, *mico*, I shine). A group of minerals, distinguished by being easily split into thin elastic plates, composed of silicates of alumina and various earths and alkalies, and largely developed in crystalline rocks. "Abrak," is the best known Indian name for this mineral.

Mica schist—A metamorphic foliated rock composed of mica and quartz.

Miliolite—A finely oolitic limestone composed in great part of the tests of foraminifera.

Nodule—An aggregation of a mineral, such as carbonate of lime, or silica, around a nucleus, or central point.

Nummulite—(Latin, *nummus*, a coin). A genus of Foraminifera, consisting of lenticular shells composed of chambers arranged in a spiral. Nummulites are so abundant in eocene beds as to be characteristic.

Obsidian—A lava that has cooled rapidly and is consequently vitreous like glass or slag. The term is especially applied to vitreous acidic or trachytic lavas, composed mainly of felspar.

Oligoclase—(Greek, ὀλίγος, little; κλάω, I cleave). A species of felspar, chiefly a silicate of alumina and soda with some lime and potash, crystallizing in the anorthic or triclinic system, and commonly found in granite and other plutonic rocks.

Olivine—A tribasic silicate of magnesia and iron, usually of a greenish (olive green) colour and translucent, crystallizing in the prismatic system. The transparent form is known as chrysolite. Olivine is common in basalt, and usually occurs in imbedded grains of a dark yellowish green colour.

Oolite—(Greek ᾠόν, egg; λίθος, stone). Limestone composed of small rounded concretionary particles. From the prevalence of such limestones in the middle secondary rocks, the term "oolite" has been applied to the system of beds underlying the cretaceous.

Orthoclase—(Greek, ὀρθός, straight; κλαω, I cleave). Common felspar, essentially a silicate of alumina and potash, crystallizing in the oblique or monoclinic system, and forming an important ingredient of granite, gneiss, and many other rocks.

Ossiferous—(Latin, *os*, a bone; *fero*, I bear). Bone-bearing: applied to beds yielding bones of Vertebrata.

Outcrop—The edge or surface of a bed, where it appears on the surface of the ground.

Outlier—A portion of a bed detached from the main area by denudation.

Palæontology—(Greek, παλαιός, ancient; ὤν, being; λόγος, discourse). The science of ancient forms of life found fossil in the rocks.

Pegmatite—(Greek, πῆγμα, anything fastened together). Usually, a binary granite, composed of quartz and felspar without mica. By some German geologists, the name is applied to a granite containing orthoclase, quartz, and white mica.

Period—A subdivision of geological time.

Petrology—(Greek, πετρος, rock; λογος, discourse). The science treating of rocks, their structure and composition.

Pisolite—(Latin, *pisum*, a pea). A concretionary limestone similar to oolite, but of coarser texture, the concretions being larger.

Pitchstone—A vitreous, dark-coloured rock of igneous origin allied to obsidian, but less glassy, of resinous lustre, and frequently containing small crystals, and grains of quartz, felspar, etc

Plutonic—(*Pluto*, god of the infernal regions). Igneous rocks formed beneath the surface of the earth and not erupted, but exposed by elevatory movements of the earth's crust.

Porphyry—(Greek, πορφύρεος, purple). An igneous rock composed of

compact finely crystalline mass in which large crystals of felspar are imbedded.

Prehnite—(Named after the discoverer). A hydrous silicate of alumina and lime, crystallizing in the prismatic system, but usually occurring in reniform crystalline masses associated with zeolites.

Pumice—A kind of volcanic froth, the mass of air bubbles from the surface of lava consolidated, and forming a spongy rock, allied to obsidian in composition, but so light as to float upon water.

Pyrites—(Greek, πυρίτες, from πῦρ, fire). Iron pyrites; bisulphide of iron, crystallizing in the cubical system.

Quaquaversal—(Latin, *quaqua*, wheresoever; *verto*, I turn). Dipping on every side; applied to strata which dip in all directions towards or from a common centre.

Quartz—(German) A miner's term for pure silica, crystallizing in the hexagonal system.

Quartzite—A metamorphic rock composed entirely, or almost entirely, of silica. An altered sandstone.

Quartz-reef—A vein of silica traversing other formations.

Quartenary—A term used by some geologists for post-tertiary and recent formations.

Recent—In giology, the present epoch; the period during which no important change has taken place in the plants and animals inhabiting the earth.

Reh—Impure salt effloresceing on the surface of swampy soils, or in dry river beds. Called oos (ús) in Gujarat.

Rock—In geological writings, this word is understood to mean any mineral substance occurring in large masses. Sand and clay in large quantities form rocks, as well as limestone or granite.

Rhyolite—(Greek, from ρυομαι, I protect). A rock allied to trachyte and felsite in composition.

Saccharoid—(σακχαρ, sugar; εἶδος, form). A granular structure resembling that of loaf-sugar.

Sandstone—A rock composed of sand cemented together.

Scarp—A steep face of rock bounding a bed. The precipitous side of any rising ground.

Scoria—(Lat. *slag*). The vesicular portions of a lava flow, or the equally vesicular fragments ejected from volcanoes during eruption. The term is sometimes used as synonymous with volcanic ash, which is, however, of more general application.

Section—(Latin *seco*, I cut). A face of rocks exposed, or cut by nature or art, or represented in a drawing.

Sediment—Earthy deposit from mechanical suspension in water.

Sedimentary rocks—Rocks formed by the deposition of sediment, in seas, lakes or river beds.

Series—A collection of beds comprising several groups, connected by stratigraphical relations or by similarity of organic remains. See "group."

Shale—A consolidated and well-laminated argillaceous or clayey rock.

Shingle—Loose pebbles, especially those on the sea-shore. A coarse form of gravel.

Silica—(Latin, *silex*, a flint). Silicic acid, a compound of the elements silicon and oxygen. Quartz is the same as silica.

Siliceous—Composed partly or wholly of silica or quartz.

Silt—Fine sediment from water, especially from rivers.

Sinter—(German). a mineral formed by hot or cold springs; the former producing a siliceous, the latter a calcareous, deposit.

Slate—A fissile non-crystalline argillaceous rock, the planes of separation of which are not due to bedding, but to cleavage. This is the true geological definition; but the term is often applied to hardened shales, which are bedded, not cleaved, and to schists, which are crystalline.

Stalactite—(Greek, σταλασσω, I drop) Earthy matter forming icicle-like projections, and separated from solution in water, through the evaporation of the latter, whilst trickling down cliffs, or dropping from the roofs of caves. The material is commonly carbonate of lime, less frequently chalcedony or some other mineral.

Stratum—Pl. Strata. (Latin stratus, spread.) A bed or layer of a sedimentary rock.

Strike—A line drawn along a bed at right angles to the dip, being the intersection between the plane formed by the bed and the earth's surface, horizontal. The line of outcrop of any stratum on level ground.

Sub-metamorphic—Partially or imperfectly metamorphic. A term applicable to transition rocks such as the Champanir series which are sometimes crystalline but more frequently unaltered.

Synclinal—(συν, together; κλίνω, I incline). The curvature of strata into a trough or valley-like form.

Synclinal axis—A line drawn along the lowest portion of a synclinal curve.

System—A term applied in geology to the whole series of beds representing a sub-division of geological time, as the carboniferous system or the cretaceous system.

Talus—(Latin). The loose detritus accumulated by falling from the face of a cliff, precipice or slope, and not re-arranged by water.

Tertiary—The third or upper great division of geological time, including all formations above the cretaceous and below the deposits of the glacial epoch. The name is synonymous with Cænozoic.

Trachyte—(Greek, τραχυς, rough). A volcanic rock, usually of a pale colour, and mainly composed of felspar; a rough mass, frequently with unbedded crystals of sanidine (glassy felspar, a variety of orthoclase). Some hornblende or augite (generally, in acicular crystals) and dark-coloured mica are also present in most trachytes.

Transition—(Latin, *transeo*, I go over). The rocks forming a passage from the crystalline gneiss and schists to the fossiliferous sedimentary rocks.

Trap—(Swedish, *trappa*, a stair; treppe, German). A name originally applied to tabular greenstone and basaltic rocks, from their frequently occurring in hills with step-like terraces on the sides. The name should be restricted to stratified lavas, (flows) whether basaltic or a trachytic, and to intrusive dykes and masses of basalt, greenstone, trachyte, or similar rocks. The term is too generally used to be abandoned; and for the ancient bedded lavas, which in vast flows cover so enormous an area in India, no term equally expressive exists.

Trapdyke—An injected vein of trap rock.

Travertine—(Tiburtinus, from the river Tibur, near Rome). Calcareous tufa deposited from the water of springs holding lime in solution.

Tufa—(Italian). Any porous vesicular rock. The term is generally restricted to calcareous deposits from springs.

Tuff—A volcanic formation, an agglomerate, composed of loose material scoriæ, lapilli, etc., cemented together. The term is especially applied to subaqueous volcanic accumulations.

Unconformity, Unconformable—Strata are unconformable to each other when the lower has suffered from denudation before the deposition of the upper, or, in a minor degree, when the upper overlaps the lower. As a general rule, the planes of deposition in unconformable strata are not parallel to each other, but there are exceptions for instance, the lower bed may have been partially denuded whilst still perfectly horizontal, and a second horizontal bed may be deposited on the denuded surface of the first, without the latter having been disturbed. In this case the bedding planes in both continue parallel, although the two are quite unconformable.

Unstratified—Rocks which do not occur in layers or strata.

Variolitic—A rock structure in which a compact matrix includes many pea-like globular bodies.

Vein—In geology, a fissure filled with some mineral substance differing from that of the rock around, which is by miners technically called the "country rock."

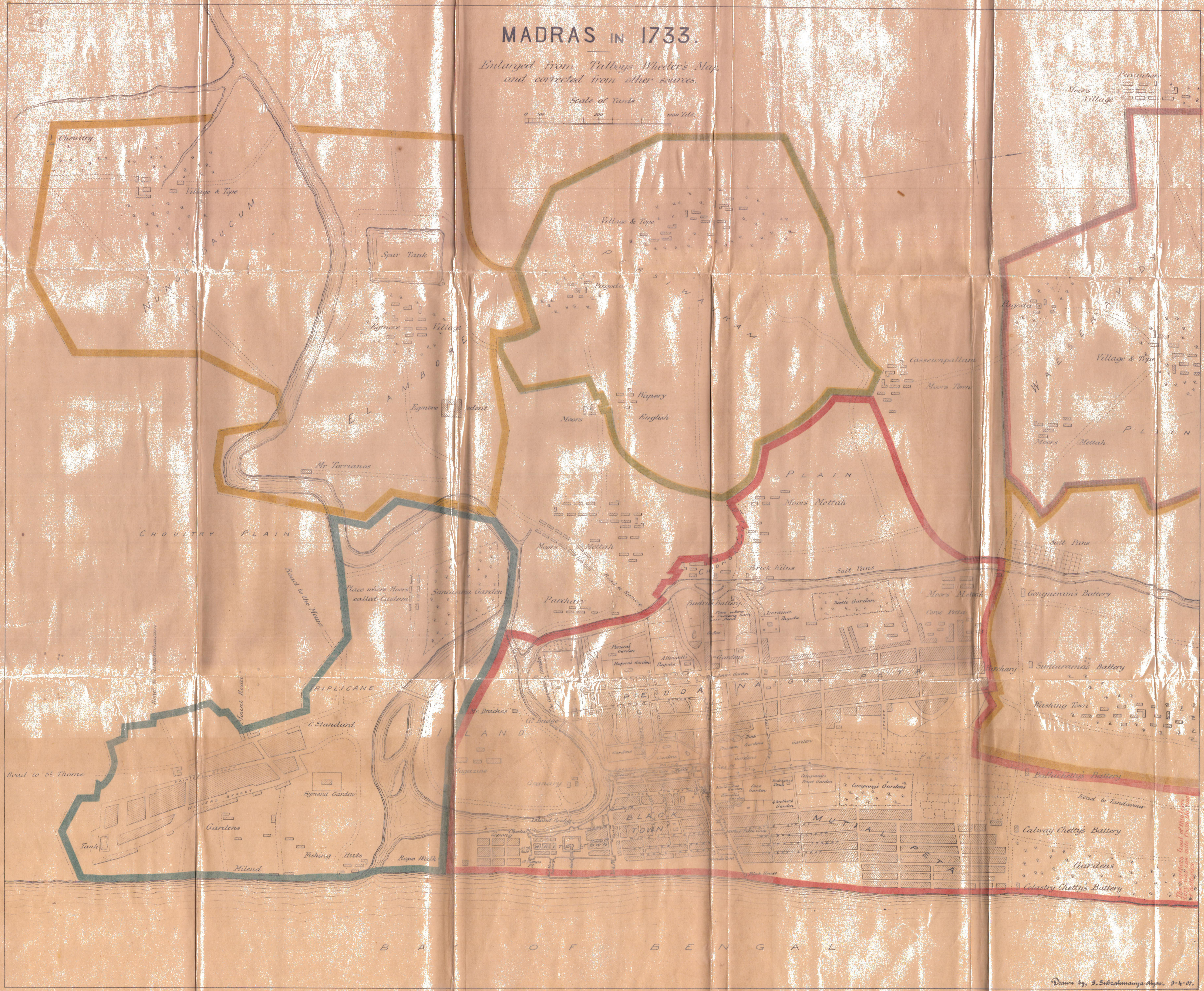
Volcanic—(Latin, *Vulcanus*, god of fire). Igneous action at the surface of the earth, in contradistinction to plutonic action, which takes place beneath the surface.

Volcanic ash—See "Ash."

Warping—An artificial process of elevating the surface of low alluvial land by allowing turbid tidal or river waters to flow over it and deposit their burden of sediment before draining them away, and repeating the operation frequently. The same process is frequently followed by nature in lowlying delta lands.

Zeolite—(Greek, ζέω, I boil). A group of minerals, hydrous silicates of alumina and various earths and alkalies, all characterized by intumescence before the blowpipe. Several of the species are common in amygdaloidal volcanic rocks, filling the cavities.

CUTCH
LITTLE RAN
GULF OF CUTCH
ARABIAN SEA
INDEX.
RECENT & SUBAERIAL MILIOLITE.
DWARKA SERIES.
GAJ SERIES.
TERTIARY
DECCAN TRAP SERIES, CRETACEOUS.
BASIC TRAP DYKES.
ACIDIC TRAP DYKES.
CALCITE & QUARTZ VEINS.
The very pale tints of red and green are given to connect the outlying (dark-tinted) patches of Baroda territory.
Map
OF
KÁTHIÁWAR
Scale, 8 Miles = 1 Inch.
GEOLOGY FROM A SURVEY BY R. BRUCE FOOTE. F.G.S. F.U.M.
STATE GEOLOGIST, BARODA.
REFERENCE
Taluka Offices
Market Towns
Taluka Offices & Market Towns
Places of Pilgrimage & Fairs
Railway Stations
Travellers Bungalows
District do
Sea Ports
Petty States
Population over 20,000
do do 10,000
do do 5,000
1 do do 2,500
2 do do 1,000
3 do do 500
4 do under 500
Heights above mean sea level
Thana Circles
1 Jhálávád
2 Hálár
3 Sorath
4 Gohelvád
Baroda
Ahmedabad Col.
Note — Approximate Boundaries shewn thus
Photozincographed
Govt. Photozinco. Office, Poona. 1897.



MADRAS IN 1733.
Enlarged from Talboys Wheeler's Map, and corrected from other sources.
Scale of Yards
Choultry
Village & Tope
NUNGAUMBAUCUM
Spur Tank
Egmore Village
ELAMBORE
Egmore Redoubt
Mr Terrianos
CHOULTRY PLAIN
Road to the Mount
Village & Tope
Pagoda
PURSEWAUKUM
Vepery
English
Moors
Casseewpallam
Moors Town
Perambur
Moors Village
Pagoda
WAESERAPADY
Village & Tope
Moors Mettah
PLAIN
PLAIN
Moors Mettah
Moors Mettah
Place where Moors collect Customs
Suncurams Garden
Purchary
Brick Kilns
Salt Pans
Salt Pans
Gengaram's Battery
Moors Mosque
TRIPLICANE
C. Standard
PEDDA NAICK PETA
ISLAND
Purchary
Sunguramas Battery
Washing Town
Road to St Thome
Symond Garden
Gardens
Tank
Fishing Huts
Milend
Rope Walk
BLACK TOWN
MUTTIAL PETA
Companys Gardens
Road to Tandiarpet
Calway Chettys Battery
Gardens
Colastry Chettys Battery
BAY OF BENGAL
Drawn by, S. Subrahmanya Aiyar. 9-4-07.

GEOLOGICAL MAP OF SANKHEDA TALUKA

BY

R. BRUCE FOOTE

F.G.S. F.U.M. &c &c

INDEX

POST-TERTIARY.
Subaerial and Alluvial

CRETACEOUS.
Deccan Trap Series.

MARINE CRETACEOUS.
Bagh Beds.

SUB-METAMORPHIC.
Champanir Series.

CRYSTALLINE.
Archæan Granites and Gneisses.

Crystalline Limestones.

Crush Breccia.

Dip and Strike.

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Govt. Photozinco. Office, Poona. 1898